SERMA TECHNOLOGIES

HAMAMATSU PHOTODIODES (DPD-S8576)
EVALUATION REPORT
(GLAST Project)
REPORT E01P1435 - JUNE 2002

This evaluation was performed for:

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1. INTRODUCTION

1.1 Purpose.

In order to evaluate the HAMAMATSU Dual PIN photoDiodes (DPD) used in the GLAST project (Gamma-Ray Large Area Telescope) by CEA Saclay (Commissariat à l'Energie Atomique) the evaluation plan described in the next pages was conducted by SERMA TECHNOLOGIES on 24 DPDs.

The tests performed by SERMA THECHNOLOGIES were oriented to Environmental Stress Tests, Construction Analysis, and Acoustic Microscopy.
CEA Saclay performed all Electrical and Optical tests.

1.2 Procedures & references.

PLAB009	Traiment d'une analyse, SERMA internal procedure,12/03/2001
ILAB033	Analyse par microscopie acoustique, SERMA internal procedure,18/09/200
JEDEC J-STD035	Acoustic microscopy for non hermetic encapsulated electronics components
IEC-6008-2-21	Bending test Ub, method 1
K03-B70219 RevA	Hamamatsu Delivery Specification of custom Dual PIN photodiode S8576
LAT-SS-00391-01	Dual PIN photodiode tests plan, Saclay
SED-GLAST-Y5300-129PB	Procédure de mesure des caractéristiques électriques des DPDs, Saclay
SEDI-GLAST-Y5300-182PA	Procédure de mesure des caractéristiques optiques des DPDs, Saclay

2. CONCLUSION

- At initial acoustic microscopy test no delamination was observed on the 22 DPDs (see specific report E01P1435/01).

- On the two DPDs with high dark current, the EBIC inspection did not revealed any significant damage at die surface (see specific report E01P1435/03).

- The different temperature & humidity stresses performed show a humidity sensitivity of epoxy resin. We recommend a particular attention for the component storage before use.

- It seems that the main failure mode observed on epoxy resin (cracks) is linked to the low temperature.
  Three DPDs were found with crack on epoxy resin:
  - One after thermal cycles at -30°C/80°C (# 126),
  - One at –40°C/90°C (# 109),
  - One after 96 hours over the 168 hours storage at –40°C (# 122).

  To check this point, thermal cycles –40°C / 30°C could be done on new samples

- There is no systematic correlation on the results between the electrical - optical and the acoustic microscopy tests:
  On the three electrically dead DPDs (only PIN B): one has crack (# 126) and the two others have only delamination (# 108, 110). Note when the PIN B is dead the capacitance of the PIN A decreases of about 9%.
  One of the 8 DPDs with delamination has a green sensitivity lost of respectively 20% and 10% for PIN A and B.

3. EVALUATION PLAN

All tests described in the following plan were conducted to evaluate the use of HAMAMATSU DPDs in the space project GLAST.

3.1 Tg (Glass Transition) measurement on epoxy resin.

Before to start all environmental stress tests, we have to know the temperature limit on epoxy resin used in DPDs. A DSC (Differential scanning calorimetry) was done on an epoxy sample from DPD used for construction analysis.

3.2 Construction Analysis

A construction analysis was done on one DPD in order to know the state of the art of HAMAMATSU Dual Pin PhotoDiodes.
A specific report was done for this evaluation (E01P1435/01)

3.3 Acoustic Microscopy Analysis

An initial acoustic microscopy was performed on all devices (#85 and 89 excepted) in order to detect potential delaminations at various interfaces (epoxy / die, epoxy / ceramic, die attach)

Before starting the acoustic microscopy, a weighing of all components was done

3.4 Drying (humidity lost)

After acoustic microscopy, all components were dried, at a lower temperature than Tg, up to recover either their initial weight or a lower weight. The drying limit will be obtained when humidity lost is complete (asymptotic curve). Successive weighing did the weight control.

3.5 Humidity Absorption

12 components, from drying test, divided in two cells of 6 components (1 with high dark current), were submitted to a temperature & humidity stress test.
One test was performed at 30°C/60% RH, the other one at 50°C/90%RH.
The humidity absorption was also measured by successive weighing and considered achieved when the component weight was stabilised (asymptotic curve).
At the end of the test, to evaluate the humidity influence, two components (including high dark current part) of each cell were submitted to an acoustic microscopy and electrical measurements.

3.6 Thermal cycles

The remaining components from temperature and humidity test cells, without backing, and 10 components from drying test cell were submitted to thermal cycles test at different temperature ranges
The following conditions were applied during thermal cycles test:

- 40 cycles around 96 hours at 0°C / 50°C
- 40 cycles around 96 hours at -10°C / 60°C
- 40 cycles around 96 hours at -20°C / 70°C
- 40 cycles around 96 hours at -30°C / 80°C
- 40 cycles around 96 hours at -40°C / 90°C

At the end of each thermal cycles test, one component of each cell (dry test, 30°C/60%RH test, 50°C/90%RH test) was removed and submitted to an acoustic microscopy and at CEA to electrical and optical measurements.

3.7 EBIC (Electrons Beam Induced Current) evaluation

An EBIC evaluation was performed on three components. The goal of this test was to inspect the die surface and try to explain why these four components revealed a higher dark current than the other parts.
A specific report was done for this evaluation (E01P1435/03)

4. COMPONENT REPARTITION

The table hereafter gives the component repartition according to the different tests performed.

R parts removed for measurements

S sample for Tg measurement

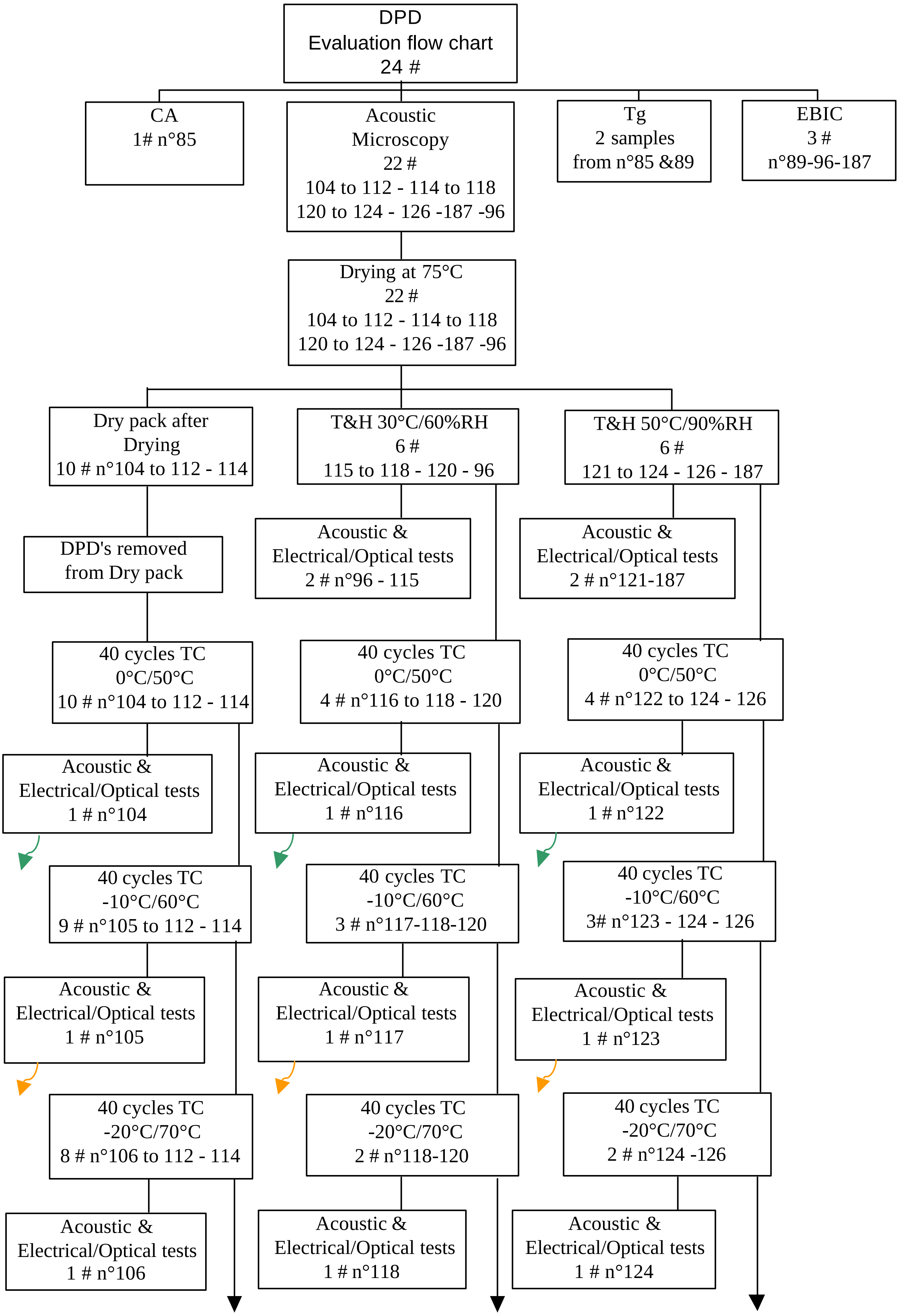
R parts with beginnig or partial delamination

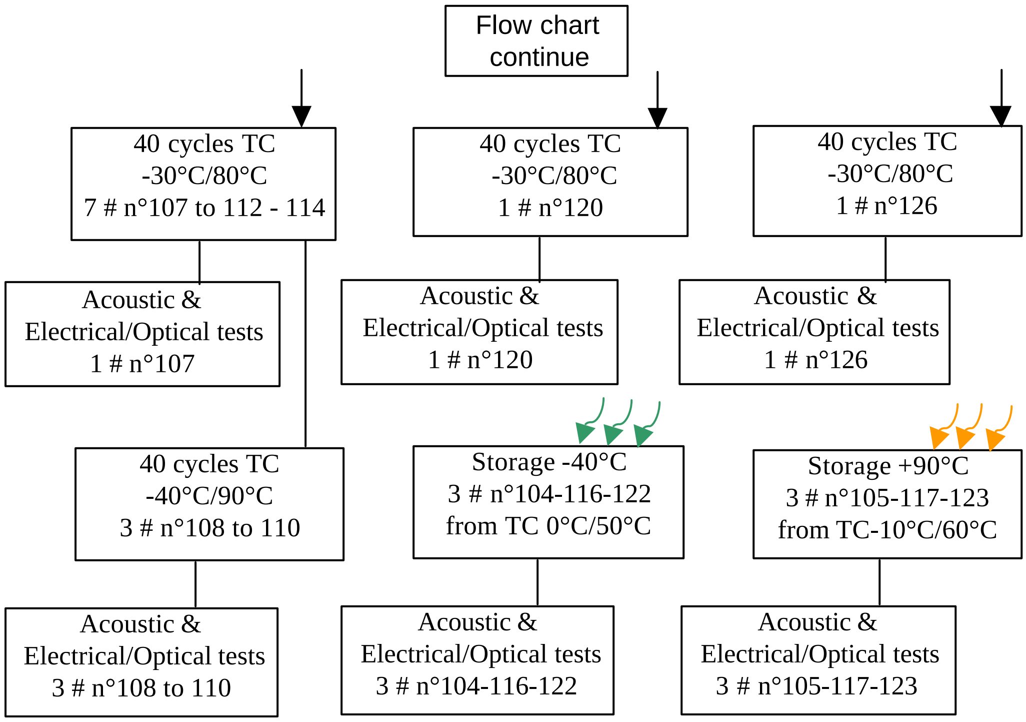
R parts with crak on epoxy

* parts electrically dead

							T & H		Thermal cycles					Storage	
DPD #	CA	EBIC	Tg	Weighing at reception	Initial Acoustic	Drying	30°C 60%RH	50°C 90%RH	40 cycles 0°C/50°C	40 cycles -10°C/60°C	40 cycles -20°C/70°C	40 cycles -30°C/80°C	40 cycles -40°C/90°C	168 hrs -40°C	168 hrs 90°C
104				X	X	X			**R**					**R**	
105				X	X	X			X	**R**					**R**
106				X	X	X			X	X	**R**				
107				X	X	X			X	X	X	**R**			
108				X	X	X			X	X	X	X	**R***		
109				X	X	X			X	X	X	X	**R**		
110				X	X	X			X	X	X	X	**R***		
111				X	X	X			X	X	X	X			
112				X	X	X			X	X	X	X			
114				X	X	X			X	X	X	X			
115				X	X	X	**R**								
116				X	X	X	X		**R**					**R**	
117				X	X	X	X		X	**R**					**R**
118				X	X	X	X		X	X	**R**				
120				X	X	X	X		X	X	X	**R**			
121				X	X	X		**R**							
122				X	X	X		X	**R**					**R**	
123				X	X	X		X	X	**R**					**R**
124				X	X	X		X	X	X	**R**				
126				X	X	X		X	X	X	X	**R***			
85	X		**S**												
89		X	**S**												
96		X		X	X	X	**R**								
187		X		X	X	X		**R**							

5. EVALUATION FLOW-CHART




Flow chart continue
40 cycles TC -30°C/80°C 7 # n°107 to 112 - 114
40 cycles TC -30°C/80°C 1 # n°120
40 cycles TC -30°C/80°C 1 # n°126
Acoustic & Electrical/Optical tests 1 # n°107
Acoustic & Electrical/Optical tests 1 # n°120
Acoustic & Electrical/Optical tests 1 # n°126
40 cycles TC -40°C/90°C 3 # n°108 to 110
Storage -40°C 3 # n°104-116-122 from TC 0°C/50°C
Storage +90°C 3 # n°105-117-123 from TC-10°C/60°C
Acoustic & Electrical/Optical tests 3 # n°108 to 110
Acoustic & Electrical/Optical tests 3 # n°104-116-122
Acoustic & Electrical/Optical tests 3 # n°105-117-123

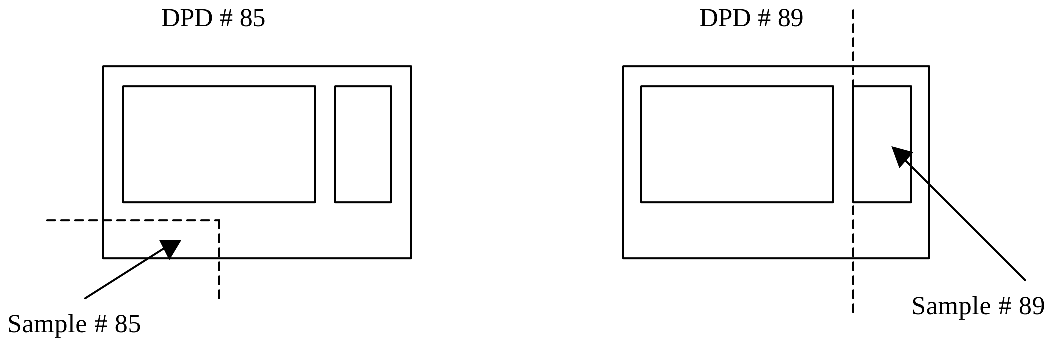
6. GLASS TRANSITION RESULTS (Tg)

Two epoxy samples were used to perform the Tg measurement (Differential Scanning Calorimetry).

The first measurement performed on an epoxy sample from DPD # 85 used for the construction analysis gives a result higher than the number given by CEA (around 100 °C versus 85 °C).

New measurements were done on an epoxy sample from DPD # 89 (PIN A) used for EBIC evaluation. The new measures were done on two different equipment and the first result found was confirmed.

6.1 Samples identification



6.2 Equipment used

- METTLER TOLEDO DSC 20 (DPD sample # 85)
- METTLER TOLEDO DSC 20 / TA Instruments Universal V3.0G (DPD sample # 89)

6.3 Tg results

DPD # 85: 3 samples: 85a – 85b – 85c

Sample # 85	Tg °C	Heating rate	Equipment
a	100.3	5°C/min	DSC20
Graph 1 b	97.3	10°C/min	DSC20
c	99.5	20°C/min	DSC20

DPD # 89: 2 samples: 89a – 89b

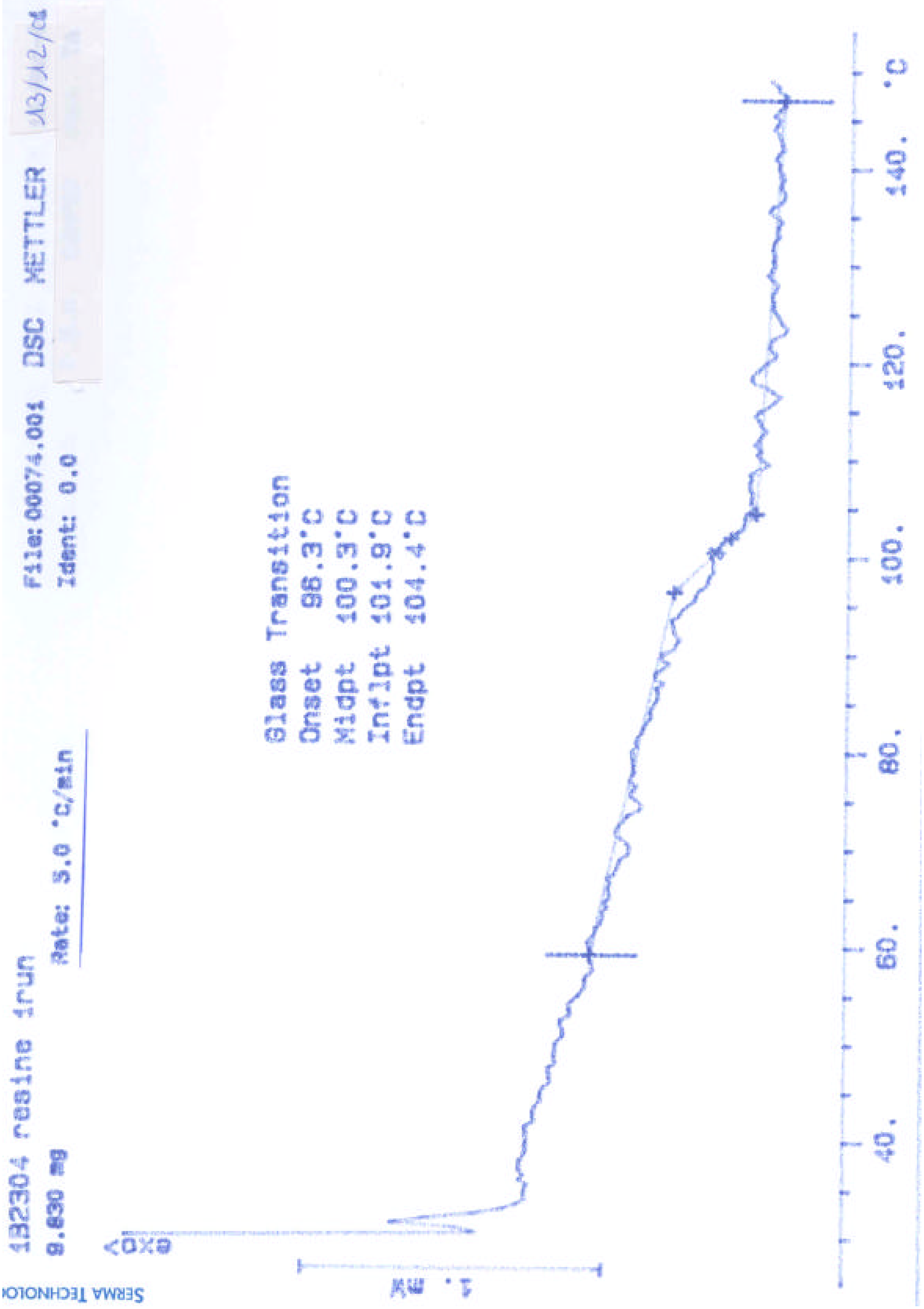
Sample # 89 a	Tg °C	Heating rate	Equipment
	97.8	20°C/min (1^{er} run)	DSC20
Graph 2	98.5	20°C/min (2^{nd} run)	DSC20

Sample # 89 b	Tg °C	Heating rate	Equipment
	99.6	20°C/min (1^{er} run)	Universal V3.0G
	95.5	20°C/min (2^{nd} run)	Universal V3.0G
Graph 3	98.9	20°C/min (3^{rd} run)	Universal V3.0G

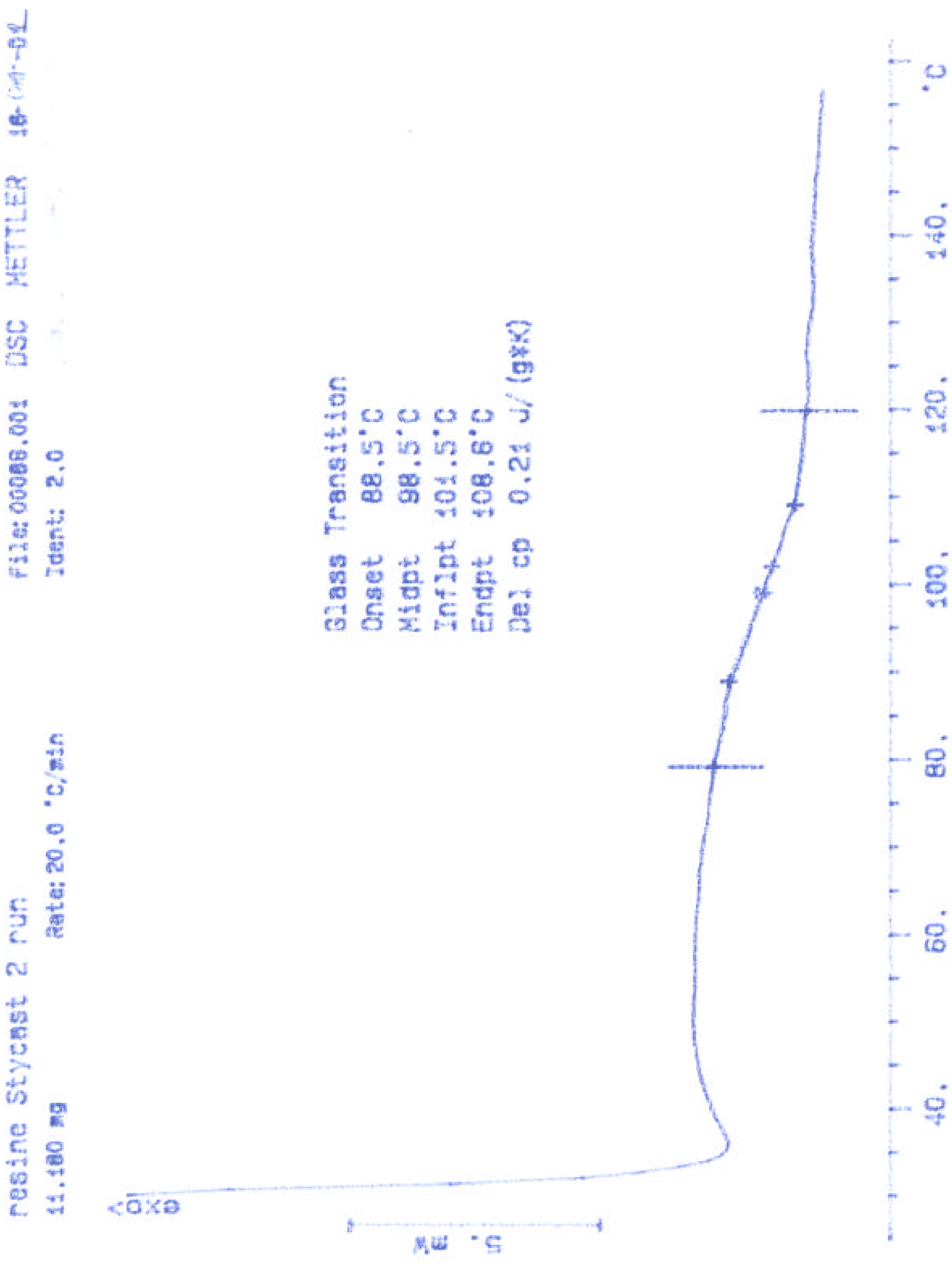
The graph measurements are given on the next pages.

The stability of Tg values on the different examined samples is evidencing a complete curing of epoxy.

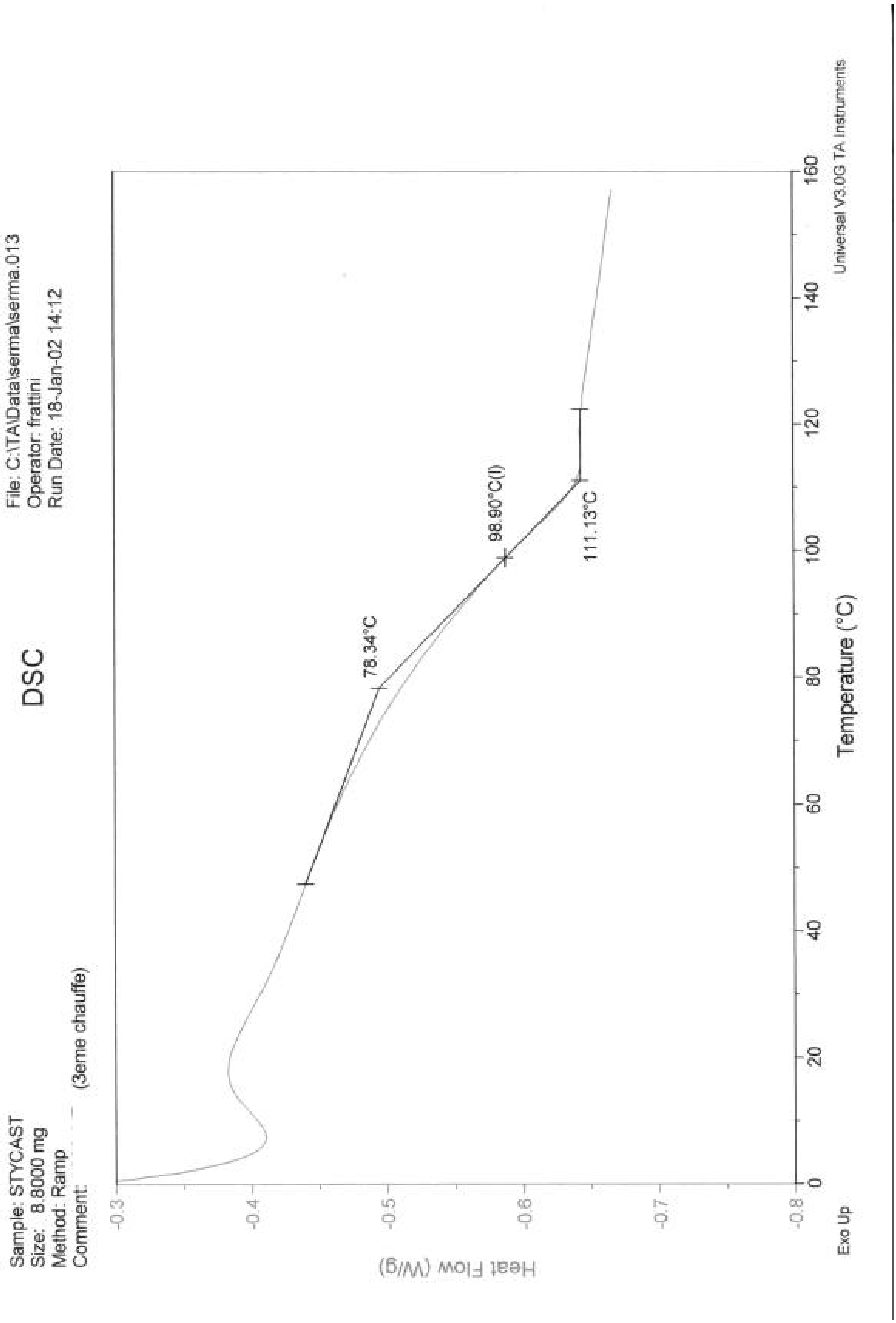
6.3.1 Graph 1


132304 resine 1run
9.830 mg
Rate: 5.0 °C/min
File: 00074.001
Ident: 0.0
DSC METTLER
Glass Transition
Onset 96.3°C
Midpt 100.3°C
Inflpt 101.9°C
Endpt 104.4°C
exo
1. mW
40.
60.
80.
100.
120.
140.
°C

6.3.2 Graph 2


resine Stycast 2 run
11.180 mg
File: 00086.001
Ident: 2.0
Rate: 20.0 °C/min
DSC METTLER
Glass Transition
Onset 88.5 °C
Midpt 98.5 °C
Inflpt 101.5 °C
Endpt 108.6 °C
Del cp 0.21 J/(g*K)
exo
5. mW
40.
60.
80.
100.
120.
140.
°C

6.3.3 Graph 3


Sample: STYCAST
Size: 8.8000 mg
Method: Ramp
Comment: (3eme chauffe)
DSC
File: C:\TA\Data\serma\serma.013
Operator: frattini
Run Date: 18-Jan-02 14:12
78.34°C
98.90°C(I)
111.13°C
Heat Flow (W/g)
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
Exo Up
0
20
40
60
80
100
120
140
160
Temperature (°C)
Universal V3.0G TA Instruments

7. CONSTRUCTION ANALYSIS RESULT

A specific report was done (E01P1435/01) for construction analysis performed on DPD sample # 85.

The analysis evidenced two potentials issues:

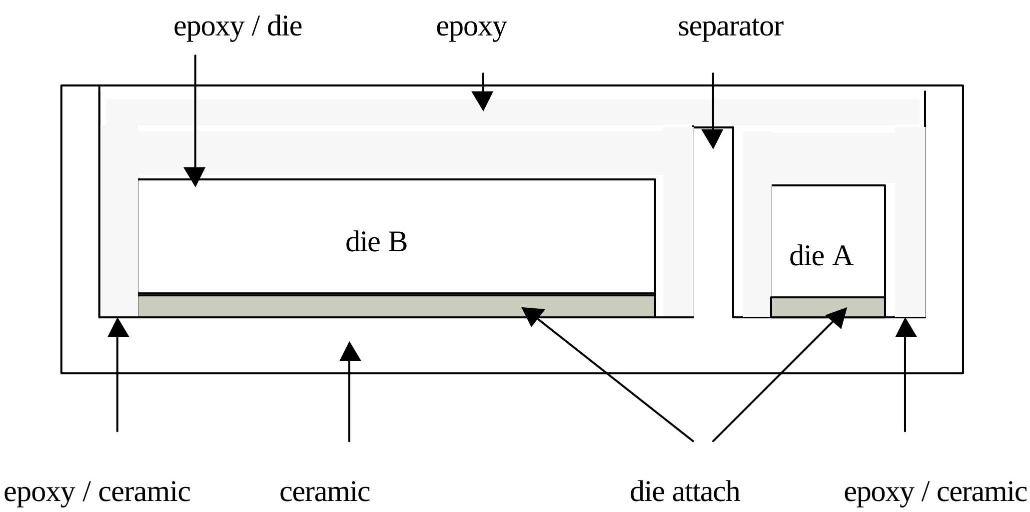
- Lacks of die attach were found on die B periphery evaluated to 15% of the die surface.
- A significant difference was found between external ceramic height and wall height.

8. ACOUSTIC MICROSCOPY RESULT

A specific report was done (E01P1435/02) for acoustic microscopy; the summarised results are listed hereafter.

There is no bake out on the parts after acoustic microscopy (before electrical and optical tests).

8.1 Interfaces identification



8.2 Acoustic microscopy results

Regarding the die attach interface no delamination was noticed on all parts observed all along the tests performed.
Note: on part # 126 after T.C. –30°C/80°C, the die attach can not be observed due to the delamination at epoxy / die interface

After T.C. –40°C/90°C, Storage at –40°C and 90°C no observation was done at die attach interface.

				Delamination at interface						
Steps	**Parts**			**Die attach**	**Epoxy/die**			**Epoxy/ceramic**		
Initial	All DPD			No	No			No		
Steps	Dry	30°C/60%RH	50°C/90%RH		Dry	30°C/60%RH	50°C/90%RH	Dry	30°C/60%RH	50°C/90%RH
After T&H		96,115	121,187	No		No	No		No	No
After TC 0°C/50°C	104	116	122	No	No	No	No	No	No	beginning
After TC -10°C/60°C	105	117	123	No	No	No	No	No	No	beginning
After TC -20°C/70°C	106	118	124	No	No	No	No	No	No	Partial
After TC -30°C/80°C	107	120	126	No	No	No	Complete	Partial	Partial	Partial
After TC -40°C/90°C	108,109,110				Partial # 108,109			Partial all DPD		

After 168hrs -40°C	104	116	122		No	No	Partial	No	No	Partial
After 168 hrs 90°C	105	117	123		No	No	No	No	No	beginning

9. DRYING RESULTS (humidity lost)

During acoustic microscopy components are put into de-ionised water at ambient temperature (during 15mn to 30mn) and can absorb humidity. So before starting acoustic microscopy a weighing of all components was done to create a referential (weight of the DPD at its arrival at SERMA).

After each acoustic microscopy measurement the components are wiped.

There is no significant weight difference on the components before and after acoustic microscopy (note the DPDs have been manipulated a lot of time at CEA for visual control, mechanical, electrical and optical measurements).

After acoustic microscopy, 71 hours drying at 75°C was necessary to remove the humidity inside the components (962µg). This result shows that the components were not completely dry at reception at SERMA.

The table and graph hereafter give the results of each component for the successive weighing.

9.1 Weighing results (before and after acoustic microscopy)

Weight (g +/- 10 µg) of the DPDs before (at the arrival at SERMA) and after the acoustic microscopy (immerged in water during about 15mn)

DPD #	096	104	105	106	107	108	109	110	111	112	114
before	1,59382	1,58719	1,59329	1,63841	1,64063	1,64519	1,63637	1,63517	1,62935	1,65981	1,64172
after	1,59385	1,58721	1,59330	1,63843	1,64066	1,64522	1,63638	1,63519	1,62936	1,65982	1,64173

DPD #	115	116	117	118	120	121	122	123	124	126	187
before	1,60860	1,63436	1,63008	1,63779	1,63767	1,60843	1,61903	1,62011	1,62846	1,62898	1,62996
after	1,60861	1,63437	1,63009	1,63780	1,63767	1,60843	1,61905	1,62011	1,62849	1,62899	1,62998

We measure a mean increase of the DPD weight of 15µg, so the acoustic test for relatively wet DPD do not change a lot its weight.

9.2 Weighing results (Drying test)

Weight (g +/- 10 µg) of the DPDs after the drying test (71h at 75°C)

DPD #	096	104	105	106	107	108	109	110	111	112	114
Weight	1,59297	1,58635	1,59251	1,63745	1,63969	1,64420	1,63525	1,63413	1,62832	1,65877	1,64080

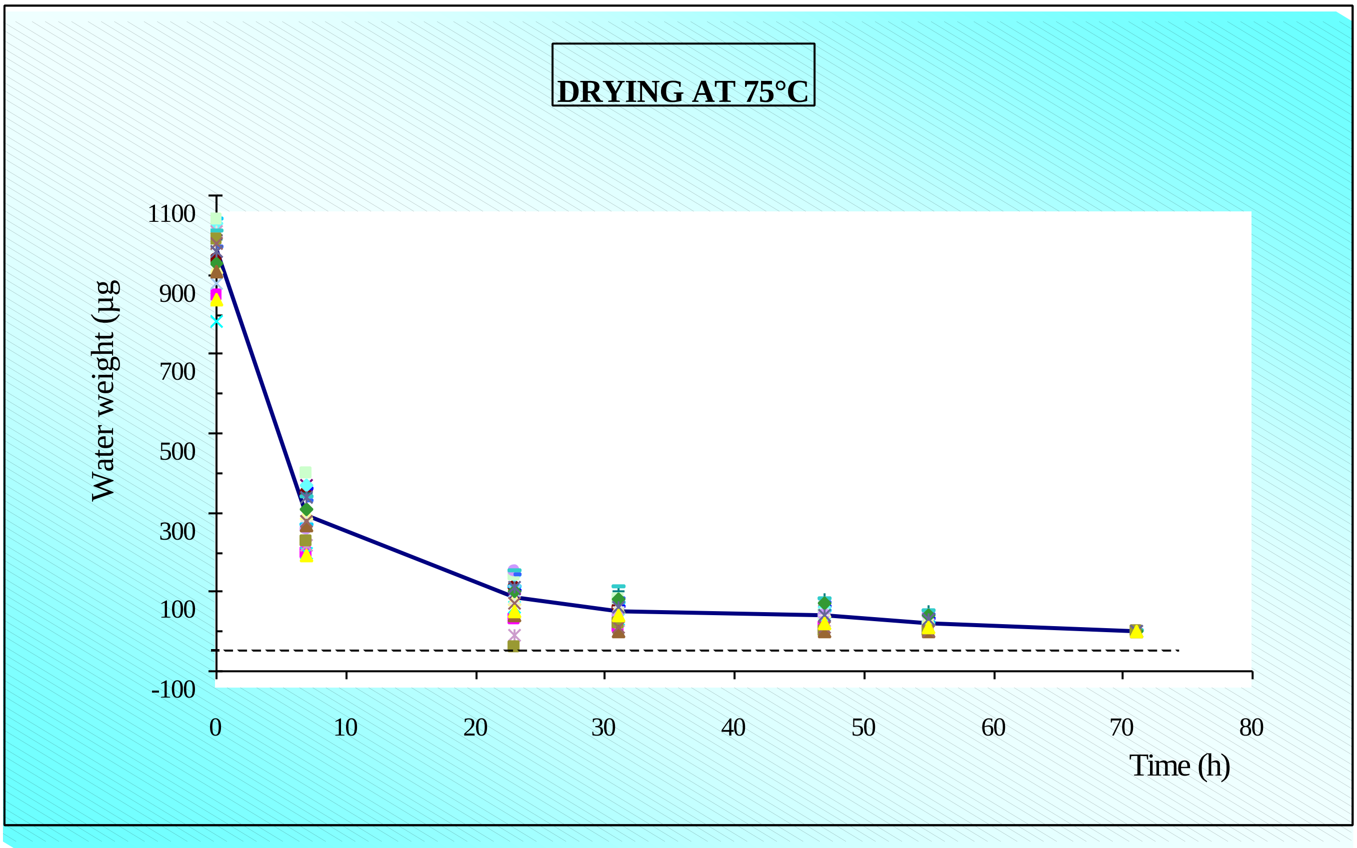
DPD #	115	116	117	118	120	121	122	123	124	126	187
Weight	1,60772	1,63335	1,62908	1,63678	1,63670	1,60742	1,61810	1,61912	1,62755	1,62800	1,62900

Water weight in the epoxy resin (µg +/- 10 µg) along the drying at 75°C is the difference between the weight at time t and the weight after drying (time 71h).

Time (h)	096	104	105	106	107	108	109	110	111	112	114
0	850	840	780	960	940	990	1120	1040	1030	1040	920
7	200	190	200	370	350	350	360	270	370	400	300
23	30	50	60	80	110	150	100	110	140	140	80
31	10	40	30	60	60	100	60	70	80	80	60
47	10	20	20	50	40	80	60	50	60	40	50
55	0	10	10	30	10	50	30	20	40	10	30
71	0	0	0	0	0	0	0	0	0	0	0

Time (h)	115	116	117	118	120	121	122	123	124	126	187	mean
0	880	1010	1000	1010	970	1010	930	990	910	980	960	962
7	280	220	260	280	330	340	310	230	270	280	340	295
23	100	-10	150	70	140	150	100	-40	40	70	110	88
31	60	0	40	60	80	110	80	20	0	10	60	53
47	60	0	40	40	70	80	70	0	0	10	40	40
55	30	0	40	30	40	50	40	0	0	0	30	23
71	0	0	0	0	0	0	0	0	0	0	0	0

The mean weight of water removed by the drying (71h at 75°C) is 962µg.



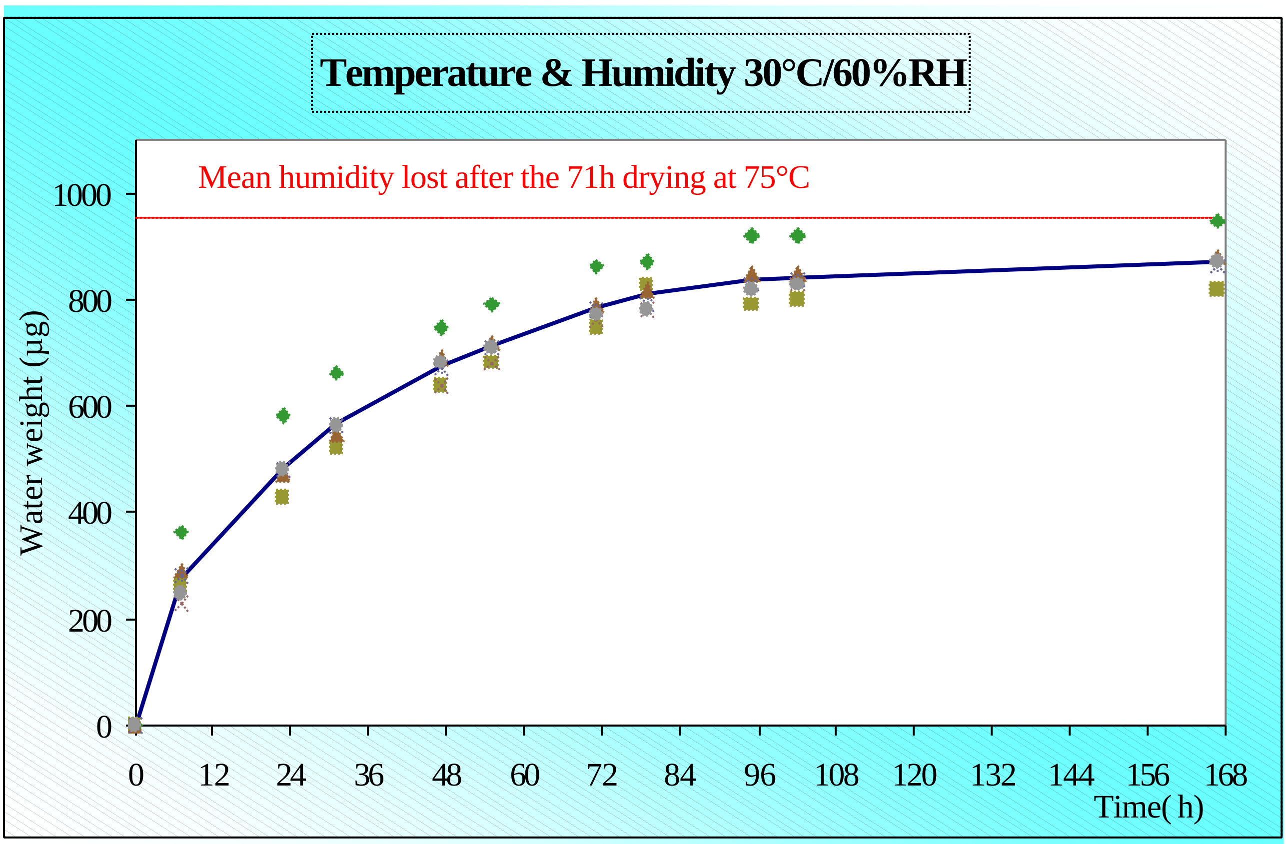
10. HUMIDITY ABSORPTION RESULTS

10.1 T&H 30°C / 60%RH

Water weight in the epoxy resin (µg +/- 10 µg) along the absorption test at 30°C and 60% RH is the difference between the weight at time t and the initial weight after the drying test.

Time (h)	096	115	116	117	118	120	MEAN
0	0	0	0	0	0	0	0
7	360	260	290	230	280	250	278
23	580	430	470	480	480	480	487
31	660	520	550	560	560	560	568
47	750	640	690	640	670	680	678
55	790	680	720	680	710	710	715
71	860	750	790	760	780	770	785
79	870	830	820	780	790	780	812
95	920	790	850	830	830	820	840
102	920	800	850	830	840	830	845
167	950	820	880	860	860	870	873

The measurements done show the epoxy resin did not absorbed their initial amount of water, in this environment 30°C/ 60%RH: 873µg after 167h regard to the 962µg of weight lost after drying of the DPD as arrived at SERMA.

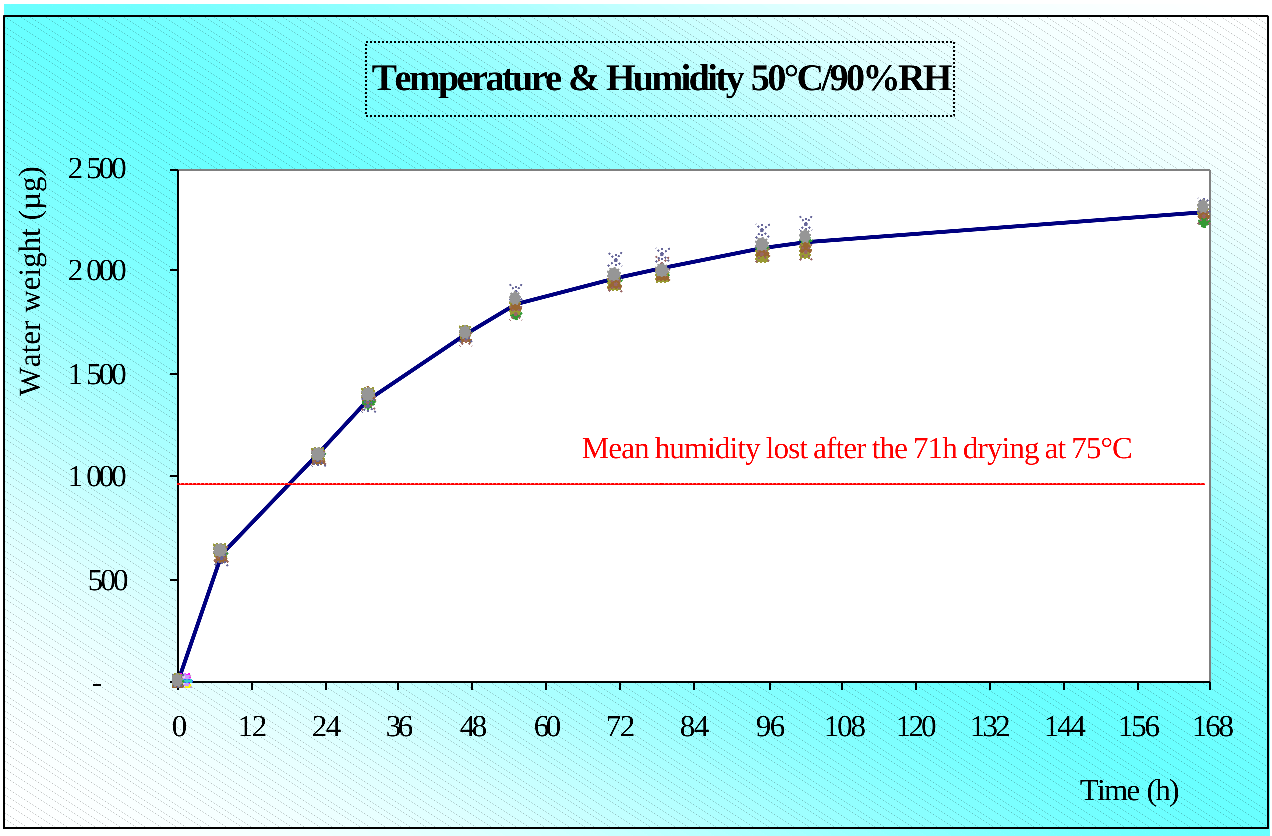


10.2 T&H 50°C / 90%RH

During the stress test the chamber temperature was between 45°-50°C.
Water weight in the epoxy resin (µg +/- 10 µg) along the absorption test at 50°C and 90% RH is the difference between the weight at time t and the initial weight after the drying test.

Time (h)	121	122	123	124	126	187	MEAN
0	0	0	0	0	0	0	0
7	620	630	620	620	600	630	620
23	1 110	1 110	1 100	1 100	1 080	1 110	1 102
31	1 360	1 390	1 400	1 360	1 350	1 390	1 375
47	1 700	1 710	1 690	1 670	1 690	1 710	1 695
55	1 800	1 820	1 840	1 800	1 900	1 870	1 838
71	1 960	1 930	1 960	1 930	2 060	1 980	1 970
79	1 990	1 970	1 990	2 038	2 090	2 000	2 013
95	2 120	2 070	2 110	2 080	2 200	2 130	2 118
102	2 160	2 100	2 130	2 100	2 230	2 170	2 148
167	2 250	2 290	2 290	2 270	2 330	2 320	2 292

The measurements done show the epoxy resin absorbed their initial amount of water (962µg) after about 20 hours. In this environment 50°C/ 90%RH, the epoxy resin could absorbed more water about 2300µg, 2.6 time the one at 30°C/50%RH.



11. THERMAL CYCLES

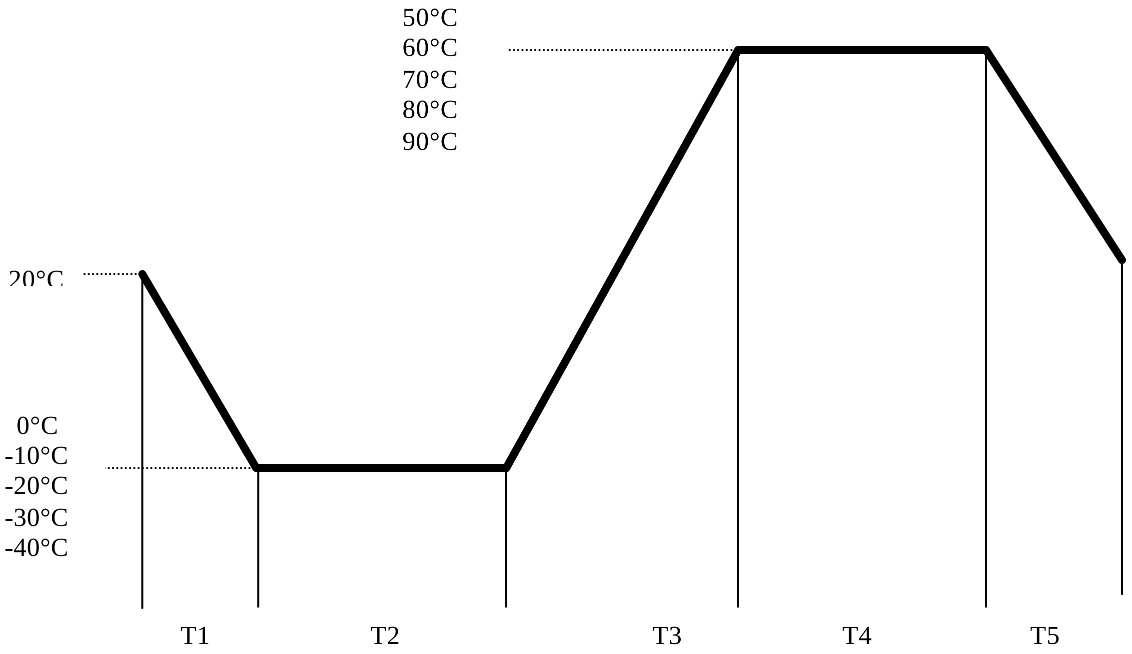
11.1 Thermal cycles description

All the components (from drying test and the two T&H tests) were submitted to the following thermal cycles.

After drying test, up to the start of thermal cycles, the components not used in T&H cells were kept in dry-pack bag.

At the end of each thermal cycle's test, one component of each cell was removed to perform acoustic microscopy and electrical tests.

All the remaining components were submitted to a new thermal cycle's test at upper temperature range.



Condition	Nbr of Cycles	Step duration (minutes)					Slope	Total time
		T1	T2	T3	T4	T5	°C/min	(days)
0°C / 50 °C	40	20	30	50	30	30	1	4,4
-10°C / 60 °C	40	20	30	47	30	27	1,5	4,3
-20°C / 70 °C	40	27	30	60	30	33	1,5	5
-30°C / 80 °C	40	25	30	55	30	30	2	4,7
-40°C / 90 °C	40	30	30	60	30	35	2	5,1

11.2 Thermal cycles results

- One part (# 126) was found with crack on epoxy resin after T.C. –30°/80°C.

- A new T.C. stress (40 cycles –40°C/90°C) was performed on 3 remaining part from dry cell.
  At the end of this supplementary stress again one part (# 109) was found with crack on epoxy resin.

12. TEMPERATURE STORAGE

Following these defects, a storage at low temperature (-40°C) was performed on the 3 DPDs removed after T.C. 0°C/50°C for tests and a storage at high temperature (90°C) was performed on the 3 DPDs removed after T.C. -10°C/60°C

The different parts were set inside and removed from the chambers at room temperature (25°C).
For the Low temperature storage, the ramp down and the ramp up were about 0.5°C / minute
For High temperature, the ramp up was around 1°C / minute, and the down one about 0.5°C/minute.

12.1 Low temperature results

One of the DPDs, # 122 was found with crack on epoxy resin after 96 hours over the 168 hours storage at – 40°C.

12.2 High temperature results

No defect found after 168 hours at 90°C.

13. ELECTRICAL & OPTICAL TESTS

Measurements has been performed at C.E.A:

➢ Electrical
- Dark Current of the 2 PIN photodiodes (A and B), the DPD polarized at 70V
- Capacitance of the 2 PIN photodiodes (A and B), the DPD polarized at 70V at 1MHz

➢ Optical
- Sensitivity of the 2 PIN photodiodes (A and B), the DPD polarized at 70V illuminated at 525nm
- Sensitivity of the 2 PIN photodiodes (A and B), the DPD polarized at 70V illuminated at 660nm

Note as the working temperature of the DPDs is an important parameter essentially for the Dark Current, we have used two DPDs as reference (#100-103) to correct this dependence.

The results are summarized in the following tables and graphs.
Note the Dark Current measurements of the DPDs of return #3 have greater incertitude because the temperature was not well stabilized and so the correction with the reference DPDs were not so good.

There is no systematic correlation on the results between the electrical - optical and the acoustic microscopy tests:

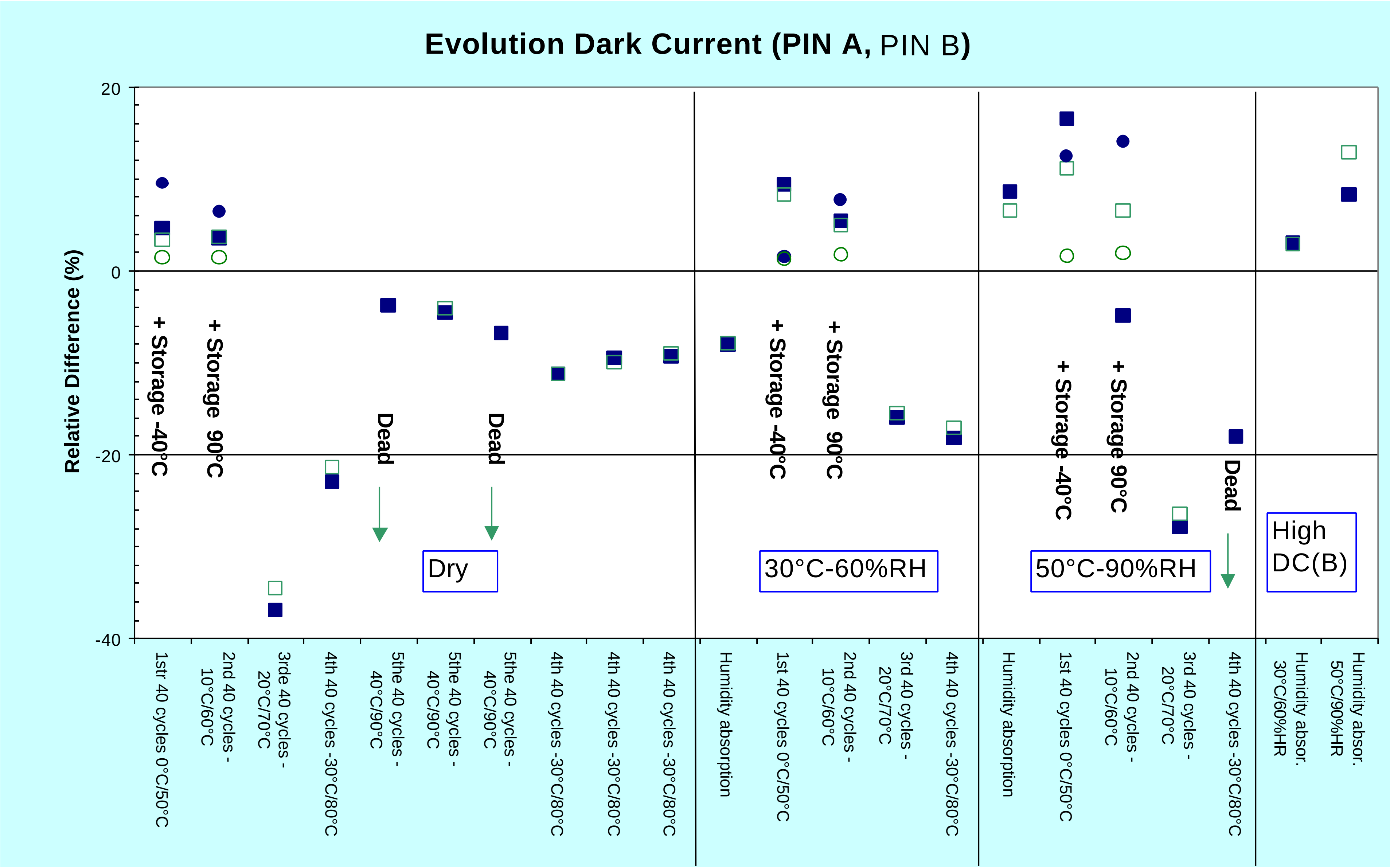
- On the three electrically dead DPDs (only PIN B): one has crack (# 126) and the two others have only delamination (# 108, 110). Note when the PIN B is dead, the capacitance of the PIN A decreases of about 9%.
- On the three DPDs with crack, one (# 126) is electrically dead (only PIN B) and the two others have green sensitivity lost probably induced by an air gap between epoxy and die (for # 122 on PIN A and B respectively 20% and 10% and for # 109 only PIN B 8%).
- On the 8 with delamination: 6 are still working and 2 are electrically dead (only PIN B). We have to investigate which contact is lost.

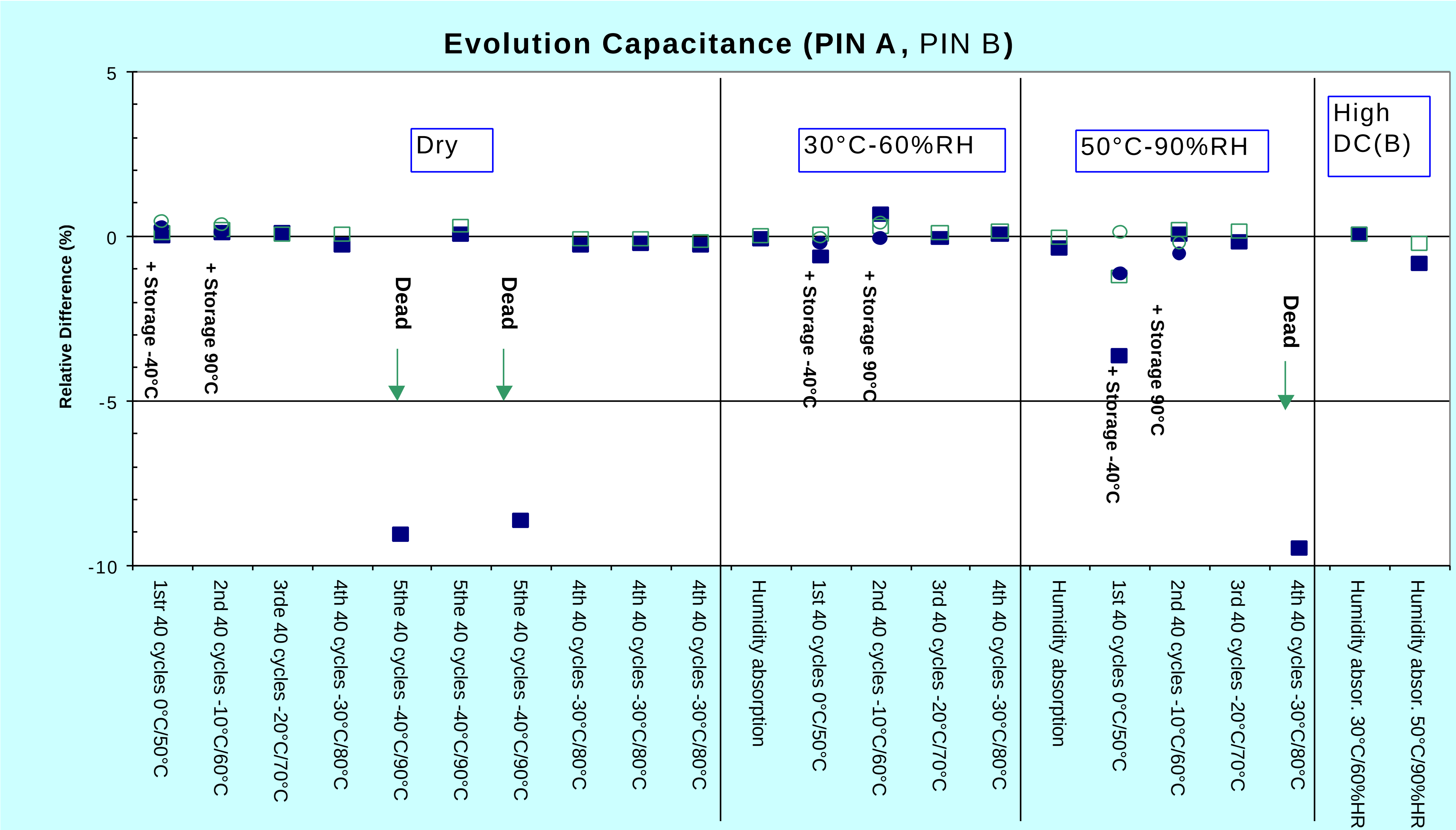
DPD#	ID(A) nA	ID(B) nA	Ct(A) pF	Ct(B) pF	S(A) 525nm A.U.	S(A) 660nm A.U.	S(B) 525nm A.U.	S(B) 660nm A.U.	Return #	Test at SERMA
	Measurements before sending at SERMA **To**									
104	0,47	1,30	15,54	63,67	207	820	1184	913	2	1st 40 cycles 0°C/50°C (dry)
105	0,49	1,24	15,55	63,57	207	824	1233	932	2	2nd 40 cycles -10°C/60°C (dry)
106	0,53	1,49	15,64	63,62	213	825	1238	921	3	3rde 40 cycles -20°C/70°C (dry)
107	0,48	1,47	15,63	63,58	217	838	1246	936	3	4th 40 cycles -30°C/80°C (dry)
108	0,52	1,63	15,58	63,60	211	836	1238	927	4	5th 40 cycles -40°C/90°C (dry)
109	0,50	1,50	15,67	63,48	216	841	1252	943	5	5th 40 cycles -40°C/90°C (dry)
110	0,57	1,59	15,57	63,50	212	834	1235	932	5	5th 40 cycles -40°C/90°C (dry)
111	0,54	1,74	15,62	63,39	216	850	1261	941	4	4th 40 cycles -30°C/80°C (dry)
112	0,54	1,62	15,63	63,68	221	855	1277	943	4	4th 40 cycles -30°C/80°C (dry)
114	0,55	1,83	15,57	64,67	215	852	1239	938	4	4th 40 cycles -30°C/80°C (dry)
115	0,52	1,56	15,49	63,21	209	823	1242	924	1	Humidity absorption 30°C/60%RH
116	0,43	1,28	15,72	63,62	220	853	1248	943	2	1st 40 cycles 0°C/50°C (30°C/60%RH)
117	0,47	1,58	15,61	63,56	213	850	1274	956	2	2nde 40 cycles -10°C/60°C (30°C/60%RH)
118	0,46	1,34	15,66	63,37	213	836	1246	928	3	3rde 40 cycles -20°C/70°C (30°C/60%RH)
120	0,50	1,35	15,69	64,44	210	838	1212	933	3	4th 40 cycles -30°C/80°C (30°C/60%RH)
121	0,50	1,52	15,61	63,61	211	845	1240	944	1	Humidity absorption 40-50°C/90%RH
122	0,44	1,42	15,53	63,17	209	844	1252	960	2	1st 40 cycles 0°C/50°C (40-50°C/90%RH)
123	0,58	1,64	15,57	64,44	210	840	1191	927	2	2nd 40 cycles -10°C/60°C (40-50°C/90%RH)
124	0,46	1,43	15,64	63,70	211	841	1271	944	3	3rd 40 cycles -20°C/70°C (40-50°C/90%RH)
126	0,48	1,34	15,55	64,42	205	839	1183	935	3	4th 40 cycles -30°C/80°C (40-50°C/90%RH)
96	**0,44**	**4,29**	**15,57**	**64,62**	**209**	**831**	**1212**	**932**	**1**	**Humidity absorption 30°C/60%RH**
187	**0,48**	**3,44**	**15,59**	**64,14**	**210**	**852**	**1206**	**945**	**1**	**Humidity absorption 40-50°C/90%RH**

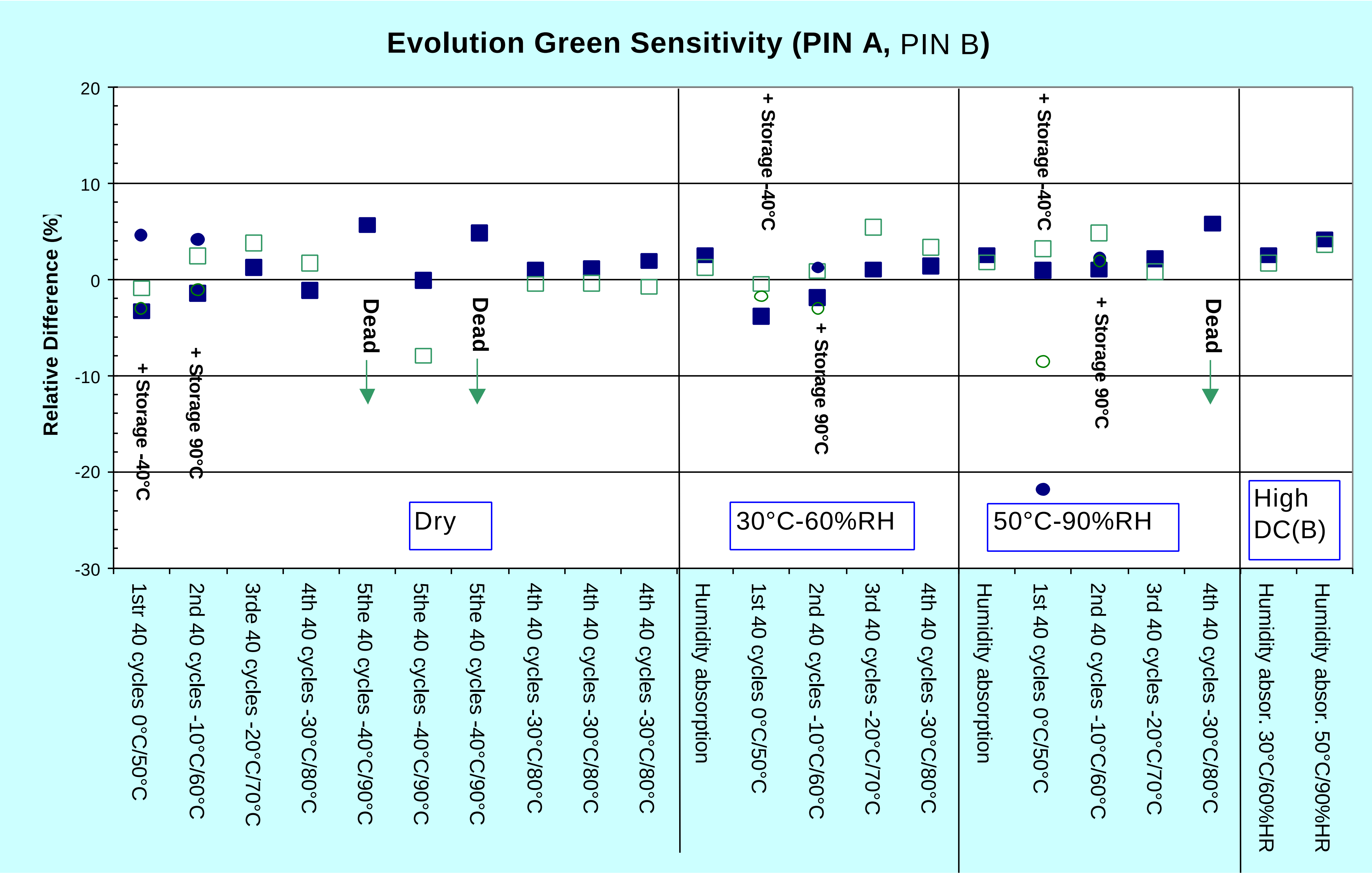
We have selected two DPDs with higher Dark Current of PIN B (**bold** in the table)

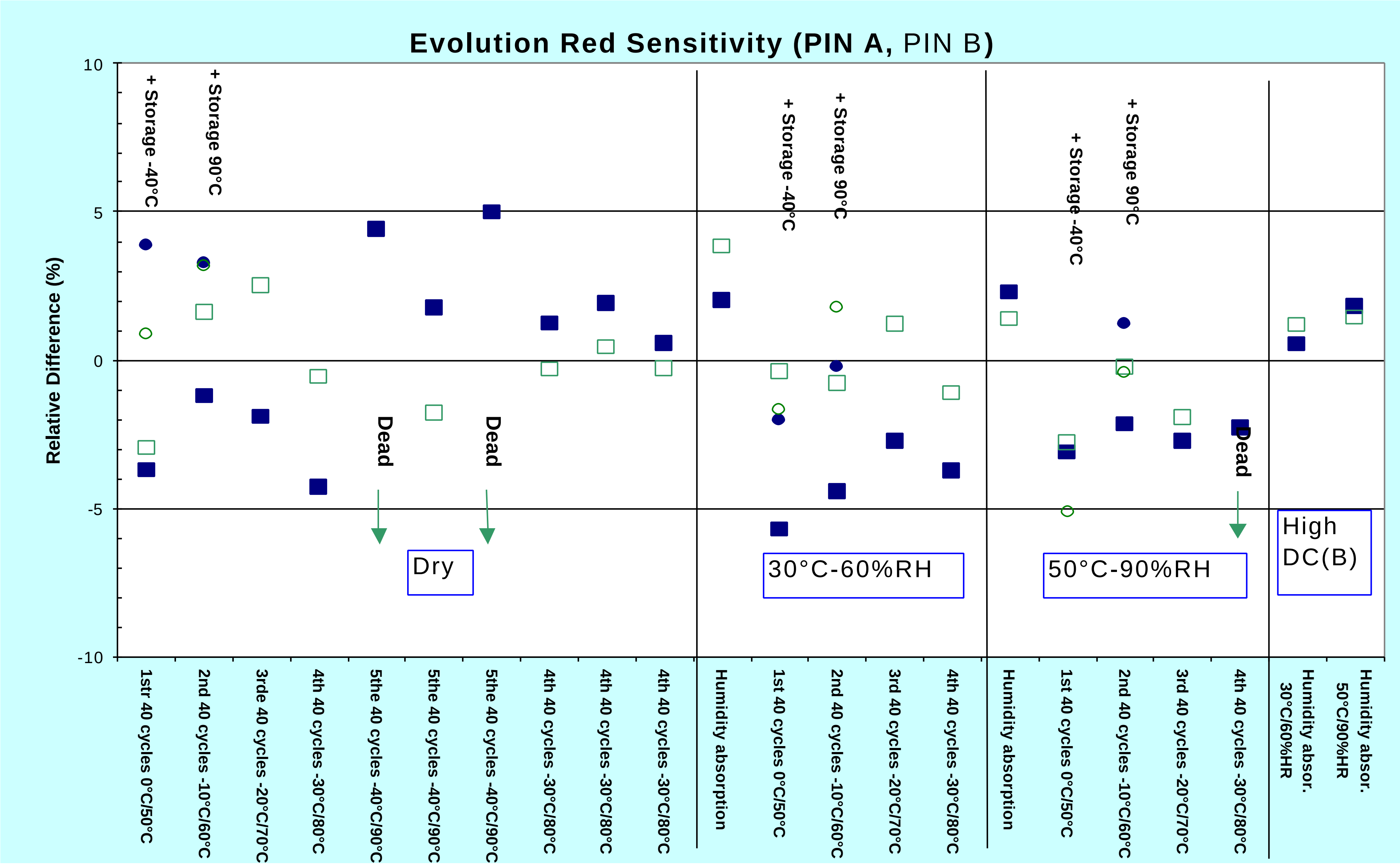
Measurements after the test at SERMA: Absolute values										
DPD#	Return #	Test at SERMA	ID(A) nA	ID(B) nA	Ct(A) pF	Ct(B) pF	S(A) 525nm A.U.	S(A) 660nm A.U.	S(B) 525nm A.U.	S(B) 660nm A.U.
104	2	1str 40 cycles 0°C/50°C (dry)	0,49	1,34	15,54	63,72	200	790	1172	886
105	2	2nd 40 cycles -10°C/60°C (dry)	0,50	1,29	15,57	63,68	204	814	1262	947
106	3	3rde 40 cycles -20°C/70°C (dry)	0,33	0,98	15,65	63,65	215	809	1284	944
107	3	4th 40 cycles -30°C/80°C (dry)	0,37	1,16	15,58	63,60	214	802	1266	931
108	4	5the 40 cycles -40°C/90°C (dry)	0,50	dead	14,17	dead	223	873	dead	
109	5	5the 40 cycles -40°C/90°C (dry)	0,48	1,44	15,67	63,66	216	856	1152	926
110	5	5the 40 cycles -40°C/90°C (dry)	0,53	dead	14,23	dead	222	875	dead	
111	4	4th 40 cycles -30°C/80°C (dry)	0,48	1,54	15,57	63,32	218	860	1253	938
112	4	4th 40 cycles -30°C/80°C (dry)	0,49	1,46	15,59	63,62	223	871	1271	947
114	4	4th 40 cycles -30°C/80°C (dry)	0,50	1,66	15,52	64,56	219	857	1228	935
115	1	Humidity absorption 30°C/60%RH	0,48	1,43	15,47	63,21	214	839	1256	959
116	2	1st 40 cycles 0°C/50°C (30°C/60%RH)	0,47	1,38	15,62	63,66	211	804	1241	939
117	2	2nde 40 cycles -10°C/60°C (30°C/60%RH)	0,50	1,66	15,72	63,73	209	812	1284	948
118	3	3rde 40 cycles -20°C/70°C (30°C/60%RH)	0,38	1,13	15,65	63,42	215	813	1312	939
120	3	4th 40 cycles -30°C/80°C (30°C/60%RH)	0,41	1,12	15,69	64,54	212	807	1251	923
121	1	Humidity absorption 40-50°C/90%RH	0,54	1,62	15,55	63,57	216	864	1260	957
122	2	1st 40 cycles 0°C/50°C (40-50°C/90%RH)	0,52	1,58	14,96	62,38	211	818	1291	933
123	2	2nd 40 cycles -10°C/60°C (40-50°C/90%RH)	0,55	1,74	15,58	64,55	212	821	1247	925
124	3	3rd 40 cycles -20°C/70°C (40-50°C/90%RH)	0,33	1,05	15,61	63,78	215	818	1280	926
126	3	4th 40 cycles -30°C/80°C (40-50°C/90%RH)	0,39	dead	14,07	dead	217	820	dead	
96	1	Humidity absorption 30°C/60%RH	0,45	4,42	15,58	64,64	214	835	1231	943
187	1	Humidity absorption 40-50°C/90%RH	0,52	3,88	15,45	64,00	218	867	1249	959
104	5	storage at -40°C	0,51	1,41	15,58	63,94	216	852	1147	921
105	5	storage at 90°C	0,52	1,33	15,57	63,80	215	851	1219	961
116	4	storage at -40°C	0,44	1,30	15,68	63,59	211	836	1225	927
117	5	storage at 90°C	0,51	1,68	15,60	63,81	215	848	1235	973
122	5	storage at -40°C	0,50	1,54	15,35	63,23	163	678	1144	911
123	4	storage at 90°C	0,66	1,81	15,49	64,30	214	850	1213	923

Measurements after the test at SERMA : Relative Value: (after test-To)/To (%)											
DPD#	Return #	Test at SERMA	ID(A)	ID(B)	Ct(A)	Ct(B)	S(A) 525nm	S(A) 660nm	S(B) 525nm	S(B) 660nm
104	2	1str 40 cycles 0°C/50°C (dry)	4,5	3,3	0,0	0,1	-3	-4	-1	-3
105	2	2nd 40 cycles -10°C/60°C (dry)	3,4	3,6	0,1	0,2	-2	-1	2	2
106	3	3rde 40 cycles -20°C/70°C (dry)	-37,0	-34,6	0,1	0,0	1	-2	4	2
107	3	4th 40 cycles -30°C/80°C (dry)	-23,0	-21,4	-0,3	0,0	-1	-4	2	-1
108	4	5the 40 cycles -40°C/90°C (dry)	-3,8	dead	-9,1	dead	6	4	dead	
109	5	5the 40 cycles -40°C/90°C (dry)	-4,6	-4,1	0,0	0,3	0	2	**-8**	-2
110	5	5the 40 cycles -40°C/90°C (dry)	-6,8	dead	-8,6	dead	5	5	dead	
111	4	4th 40 cycles -30°C/80°C (dry)	-11,3	-11,2	-0,3	-0,1	1	1	-1	0
112	4	4th 40 cycles -30°C/80°C (dry)	-9,5	-10,1	-0,2	-0,1	1	2	0	0
114	4	4th 40 cycles -30°C/80°C (dry)	-9,4	-9,0	-0,3	-0,2	2	1	-1	0
115	1	Humidity absorption 30°C/60%RH	-8,1	-8,0	-0,1	0,0	2	2	1	4
116	2	1st 40 cycles 0°C/50°C (30°C/60%RH)	9,3	8,2	-0,6	0,1	-4	-6	-1	0
117	2	2nde 40 cycles -10°C/60°C (30°C/60%RH)	5,4	4,9	0,7	0,3	-2	-4	1	-1
118	3	3rde 40 cycles -20°C/70°C (30°C/60%RH)	-16,1	-15,5	-0,1	0,1	1	-3	5	1
120	3	4th 40 cycles -30°C/80°C (30°C/60%RH)	-18,2	-17,2	0,1	0,1	1	-4	3	-1
121	1	Humidity absorption 40-50°C/90%RH	8,6	6,5	-0,4	-0,1	2	2	2	1
122	2	1st 40 cycles 0°C/50°C (40-50°C/90%RH)	16,4	11,1	-3,6	-1,3	1	-3	3	-3
123	2	2nd 40 cycles -10°C/60°C (40-50°C/90%RH)	-4,9	6,5	0,0	0,2	1	-2	5	0
124	3	3rd 40 cycles -20°C/70°C (40-50°C/90%RH)	-27,9	-26,5	-0,2	0,1	2	-3	1	-2
126	3	4th 40 cycles -30°C/80°C (40-50°C/90%RH)	-18,0	dead	-9,5	dead	6	-2	dead	
96	1	Humidity absorption 30°C/60%RH	3,0	2,9	0,0	0,0	2	1	2	1
187	1	Humidity absorption 40-50°C/90%RH	8,2	12,8	-0,9	-0,2	4	2	4	1
104	5	storage at -40°C	9,5	8,9	0,3	0,4	5	4	-3	1
105	5	storage at 90°C	6,3	7,0	0,1	0,4	4	3	-1	3
116	4	storage at -40°C	1,4	1,4	-0,2	-0,1	-4	-2	-2	-2
117	5	storage at 90°C	7,7	6,3	-0,1	0,4	1	0	-3	2
122	5	storage at -40°C	12,5	8,8	-1,2	0,1	**-22**	**-20**	**-9**	**-5**
123	4	storage at 90°C	14,0	10,8	-0,5	-0,2	2	1	2	0


Evolution Dark Current (PIN A, PIN B)
Relative Difference (%)
20
0
-20
-40
+ Storage -40°C
+ Storage 90°C
Dead
Dead
Dry
30°C-60%RH
50°C-90%RH
High DC(B)
1str 40 cycles 0°C/50°C
2nd 40 cycles - 10°C/60°C
3rde 40 cycles - 20°C/70°C
4th 40 cycles -30°C/80°C
5the 40 cycles - 40°C/90°C
5the 40 cycles - 40°C/90°C
5the 40 cycles - 40°C/90°C
4th 40 cycles -30°C/80°C
4th 40 cycles -30°C/80°C
4th 40 cycles -30°C/80°C
Humidity absorption
1st 40 cycles 0°C/50°C
2nd 40 cycles - 10°C/60°C
3rd 40 cycles - 20°C/70°C
4th 40 cycles -30°C/80°C
Humidity absorption
1st 40 cycles 0°C/50°C
2nd 40 cycles - 10°C/60°C
3rd 40 cycles - 20°C/70°C
4th 40 cycles -30°C/80°C
Humidity absor. 30°C/60%HR
Humidity absor. 50°C/90%HR


Evolution Capacitance (PIN A, PIN B)
Relative Difference (%)
5
0
-5
-10
Dry
30°C-60%RH
50°C-90%RH
High DC(B)
+ Storage -40°C
+ Storage 90°C
Dead
Dead
+ Storage -40°C
+ Storage 90°C
+ Storage -40°C
+ Storage 90°C
Dead
1str 40 cycles 0°C/50°C
2nd 40 cycles -10°C/60°C
3rde 40 cycles -20°C/70°C
4th 40 cycles -30°C/80°C
5the 40 cycles -40°C/90°C
5the 40 cycles -40°C/90°C
5the 40 cycles -40°C/90°C
4th 40 cycles -30°C/80°C
4th 40 cycles -30°C/80°C
4th 40 cycles -30°C/80°C
Humidity absorption
1st 40 cycles 0°C/50°C
2nd 40 cycles -10°C/60°C
3rd 40 cycles -20°C/70°C
4th 40 cycles -30°C/80°C
Humidity absorption
1st 40 cycles 0°C/50°C
2nd 40 cycles -10°C/60°C
3rd 40 cycles -20°C/70°C
4th 40 cycles -30°C/80°C
Humidity absor. 30°C/60%HR
Humidity absor. 50°C/90%HR


Evolution Green Sensitivity (PIN A, PIN B)
Relative Difference (%)
20
10
0
-10
-20
-30
+ Storage -40°C
+ Storage 90°C
Dead
Dead
+ Storage -40°C
+ Storage 90°C
+ Storage -40°C
+ Storage 90°C
Dead
Dry
30°C-60%RH
50°C-90%RH
High DC(B)
1str 40 cycles 0°C/50°C
2nd 40 cycles -10°C/60°C
3rde 40 cycles -20°C/70°C
4th 40 cycles -30°C/80°C
5the 40 cycles -40°C/90°C
5the 40 cycles -40°C/90°C
5the 40 cycles -40°C/90°C
4th 40 cycles -30°C/80°C
4th 40 cycles -30°C/80°C
4th 40 cycles -30°C/80°C
Humidity absorption
1st 40 cycles 0°C/50°C
2nd 40 cycles -10°C/60°C
3rd 40 cycles -20°C/70°C
4th 40 cycles -30°C/80°C
Humidity absorption
1st 40 cycles 0°C/50°C
2nd 40 cycles -10°C/60°C
3rd 40 cycles -20°C/70°C
4th 40 cycles -30°C/80°C
Humidity absor. 30°C/60%HR
Humidity absor. 50°C/90%HR


Evolution Red Sensitivity (PIN A, PIN B)
Relative Difference (%)
10
5
0
-5
-10
+ Storage -40°C
+ Storage 90°C
+ Storage -40°C
+ Storage 90°C
+ Storage -40°C
+ Storage 90°C
Dead
Dead
Dead
Dry
30°C-60%RH
50°C-90%RH
High DC(B)
1str 40 cycles 0°C/50°C
2nd 40 cycles -10°C/60°C
3rde 40 cycles -20°C/70°C
4th 40 cycles -30°C/80°C
5the 40 cycles -40°C/90°C
5the 40 cycles -40°C/90°C
5the 40 cycles -40°C/90°C
4th 40 cycles -30°C/80°C
4th 40 cycles -30°C/80°C
4th 40 cycles -30°C/80°C
Humidity absorption
1st 40 cycles 0°C/50°C
2nd 40 cycles -10°C/60°C
3rd 40 cycles -20°C/70°C
4th 40 cycles -30°C/80°C
Humidity absorption
1st 40 cycles 0°C/50°C
2nd 40 cycles -10°C/60°C
3rd 40 cycles -20°C/70°C
4th 40 cycles -30°C/80°C
Humidity absor. 30°C/60%HR
Humidity absor. 50°C/90%HR

SERMA TECHNOLOGIES

CONSTRUCTION ANALYSIS
ON A CALORIMETER PIN PHOTODIODE
FROM HAMAMATSU
REPORT E01P1435/01 – DECEMBER 10, 2001

This analysis was performed for :

CEA
Orme des Merisiers BAT 709
91191 GIF-SUR-YVETTE

Performed by : P. BARRET

Approved by : JM. ETCHARREN

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S.A. à Directoire et Conseil de Surveillance au capital de 2.301.072 € - SIRET 380 712 828 00058 – CODE APE 731 Z

INTRODUCTION

One Dual PIN photo Diode (DPD), from *HAMAMATSU*, was submitted to SERMA Technologies for construction analysis.

S/N of the part was 85.

CONCLUSION

* The analysis evidenced two questionable points :

  - Lacks of die attach were found on die B periphery evaluated to 15% of the die surface.

  - Dimensional analysis results were in accordance with data sheet tolerance (which is large). However, we found a significant difference between external ceramic height and wall height. Inducing a clear resin thickness variation, the influence of these variations should be checked on the diode operation.

* The adhesion between epoxy and dice surface appeared correct. However, the behaviour of the resin must be checked, for instance by acoustic microscopy, before and after stress.

ANALYSIS PROCESS

- Dimensional
- External visual inspection
- X-rays inspection
- Crossection – optical and SEM inspections
- Decapsulation and internal inspection

RESULTS

DIMENSIONAL

- External measurements were performed on the part.
- The dimensions and tolerances were issued from "Specification for the Calorimeter PIN photodiode Assembly" LAT-DS-00209-D1.

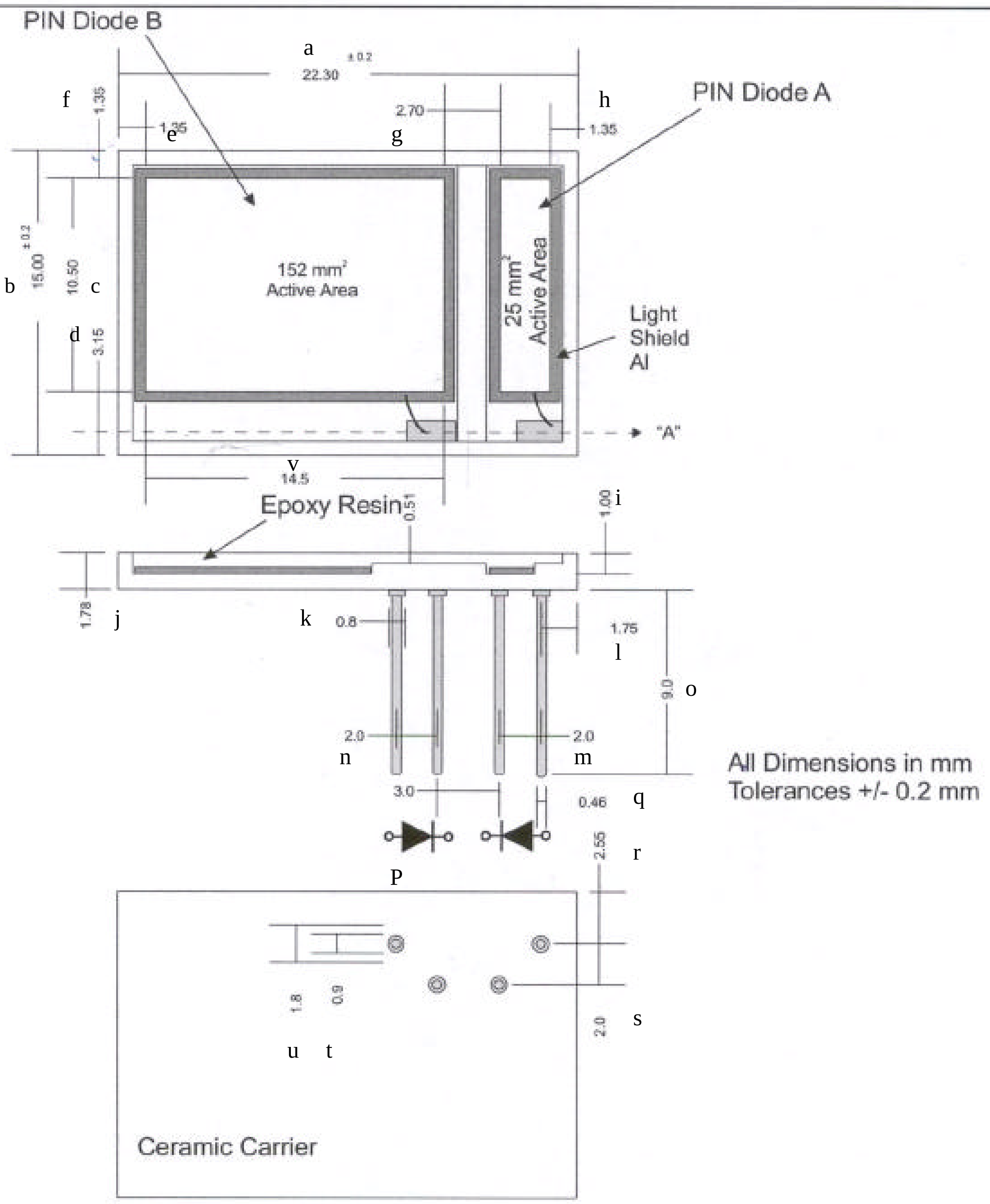


Figure 1. Mechanical Configuration of the GLAST CAL PIN Photodiode Assembly

MEASUREMENT TABLE

	Specification	Measurement	Tolerance
a	22.30	22.28	±0.2 mm
b	15.00	14.99	±0.2 mm
c	10.50	10.49	±0.2 mm
d	3.15	3.22	±0.2 mm
e	1.35	1.325	±0.2 mm
f	1.35	1.29	±0.2 mm
g	2.70	2.758	±0.2 mm
h	1.35	1.329	±0.2 mm
i	1.00	-	±0.2 mm
j	1.78	1.774	±0.2 mm
k	0.8	-	±0.2 mm
l	1.75	1.703	±0.2 mm
m	2.0	1.985	±0.2 mm
n	2.0	2.00	±0.2 mm
o	9.0	8.89	±0.2 mm
p	3.0	2.985	±0.2 mm
q	0.46	0.442	±0.2 mm
r	2.55	2.60	±0.2 mm
s	2.0	2.03	±0.2 mm
t	0.9	-	±0.2 mm
u	1.8	1.773	±0.2 mm
v	14.5	14.57	±0.2 mm

EXTERNAL VISUAL – CARRIER DESCRIPTION

- Two PIN silicon dice are mounted in a ceramic carrier.
- Four gold plated leads are used. The dice are covered with a clear epoxy which fills the ceramic case.
- The studied part was not packaged in flight packaging, toolmarks, bended leads and stains were found. Figures 1 and 2.

X-RAYS INSPECTIONS

- Top X-rays evidenced lacks of die attach material of diode B (evaluated at 15% of the die surface). They are located at the die periphery. Figure 3.
- The internal connections through gold wires / post / via and external leads are illustrated in Figure 4.

INTERNAL INSPECTION

- Each die is connected by two gold bonding wires on a bonding post.
- The component was cut in 3 parts to perform internal inspection, crossection and Tg measurement. Several acids and solvents were used to remove the clear resin. The bonding wires could not be kept intact because of stress applied during resin dissolution. Figures 5 and 6.
- Die dicing is by 100% sawing ; no significant chipout was found on die edges.

CROSSECTION

- General views of the package in section are shown in Figure 7.

- The ceramic carrier is multilayered. Top metallization level for package bonding post, one level is used for case bottom (die bonding level) ; one level is used for internal level, last one is used on case backside at lead soldering area, Figure 9.

- We found a height difference between two opposite case sides and opposite walls (≈60 µm). Figure 7.

- The internal via is made by a W compound connecting bottom case level to external level. Figures 9 and 10. The internal layer is only W compound made. The ceramic is an alumina ($Al2O3$), Zr phases were detected. Figure 10.

- The FeNi lead is soldered to the case by an AgCu solder. Figures 11 and 12. The lead and solder are covered by NiP / Au layers.

- Internal connections are performed by two Au wires per die. The interfaces observed in section on die and bonding post did not evidenced anomaly. Figure 13.

- The die is bonded on the case bottom by an Ag paste on the Au / NiP / W metallization. The interfaces were correct. Die backside is metallised with a gold layer. Figure 14.

DICE ANALYSIS

- Views of the dice are shown in Figure 15.

- The dice are silicon PIN diodes. A peripheric aluminum ring contacts the die. The sensitive area uses the most surface of the die. Figure 16.

- Details of the contact area (aluminum etched) are shown in Figure 16. Section views of the die B are shown in Figures 17 and 20.

- The die is contacted by aluminum lines on diffusions.

- The sensitive layer is covered by a thin silicon nitride over a P+ diffusion.

MATERIAL AND THICKNESS

Case	: Al, O, Zr
Metallisations	
- bonding area (post)	: Au – 1.2 to 1.9 µm
- case bottom	: NiP – 1.8 to 2.1 µm
- case backside under lead	: NiW – 1.1 to 1.3 µm
	: W – 8.5 µm
Internal layer	: W –9.7 µm
Bottom conductive layer	: W – 14 µm
Via metallization	: W
Lead	: FeNi
Lead coating	: Au – 2 µm NiP – 2 to 2.8 µm
Lead solder	: AgCu
Die	: Si – 320 µm
Die backside metallization	: Au –0 to 1 µm
Die attach	: Ag paste – 13 to 17 µm
Clear resin	: 560 to 630 µm

Active layers* and die metallization

Al – 1.15 µm
P+ - 0.5 µm
Intrinsec layer – 300 µm
N – 20 µm

* We think that the P layer was not visible after staining.

Dielectrics

Thick grown oxide – 0.4 µm
Nitride layer - ≈0.075 µm

HORIZONTAL DIMENSIONS

A diode	B diode
width : 3.45 mm	width : 11.61 mm
length : 11.54 mm	length : 15.6 mm
surface : 39.8 mm^2	surface : 181 mm^2

Bonding wire : Au - ∅ = 30 µm

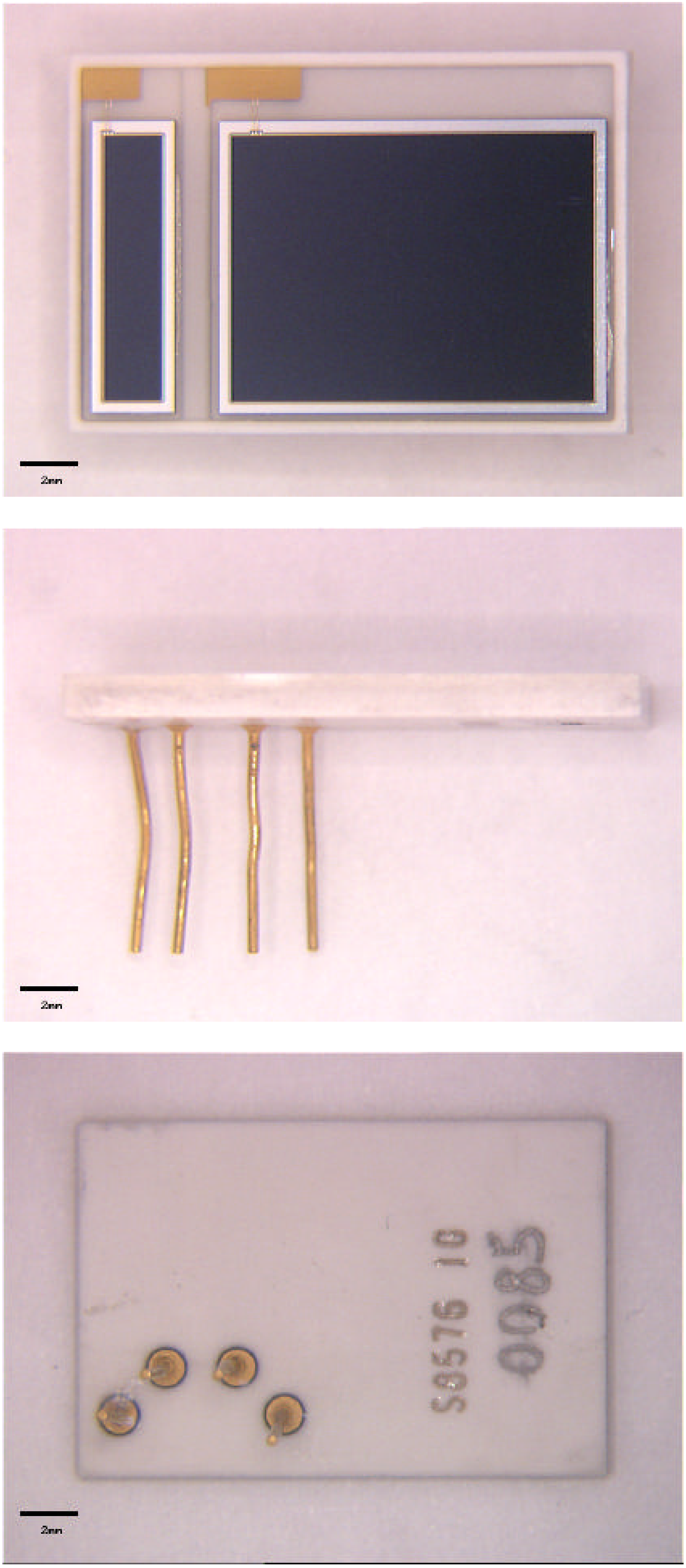


Figure 1. External views of the post case, mag ≈4X.

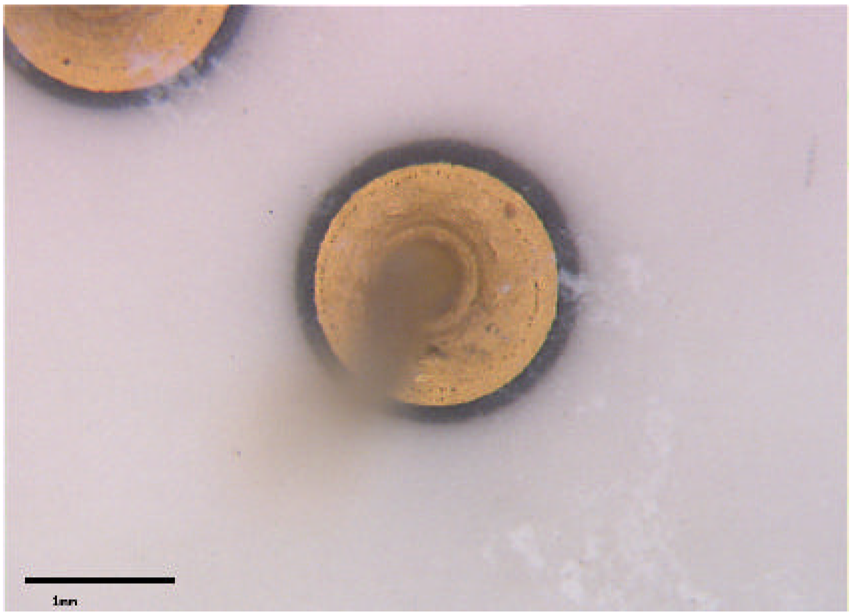
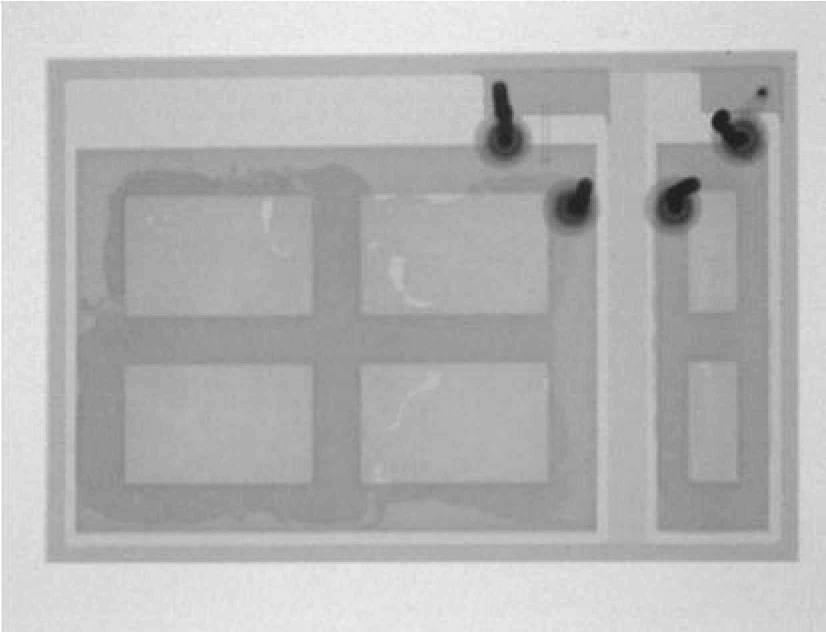


Figure 2. Detail of a lead assembly on the package, mag ≈22X.



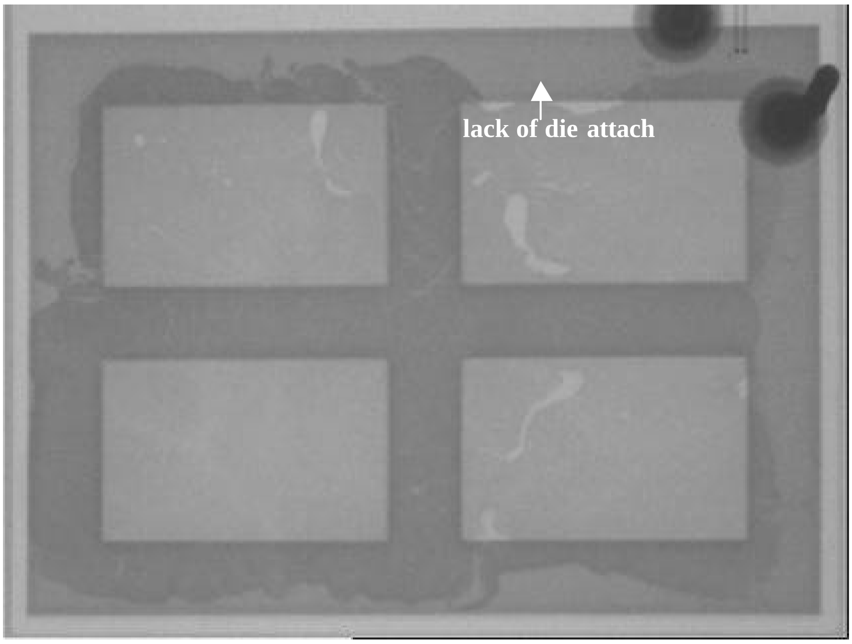


Figure 3. X-rays views of the package and detail of the die B mounting material.

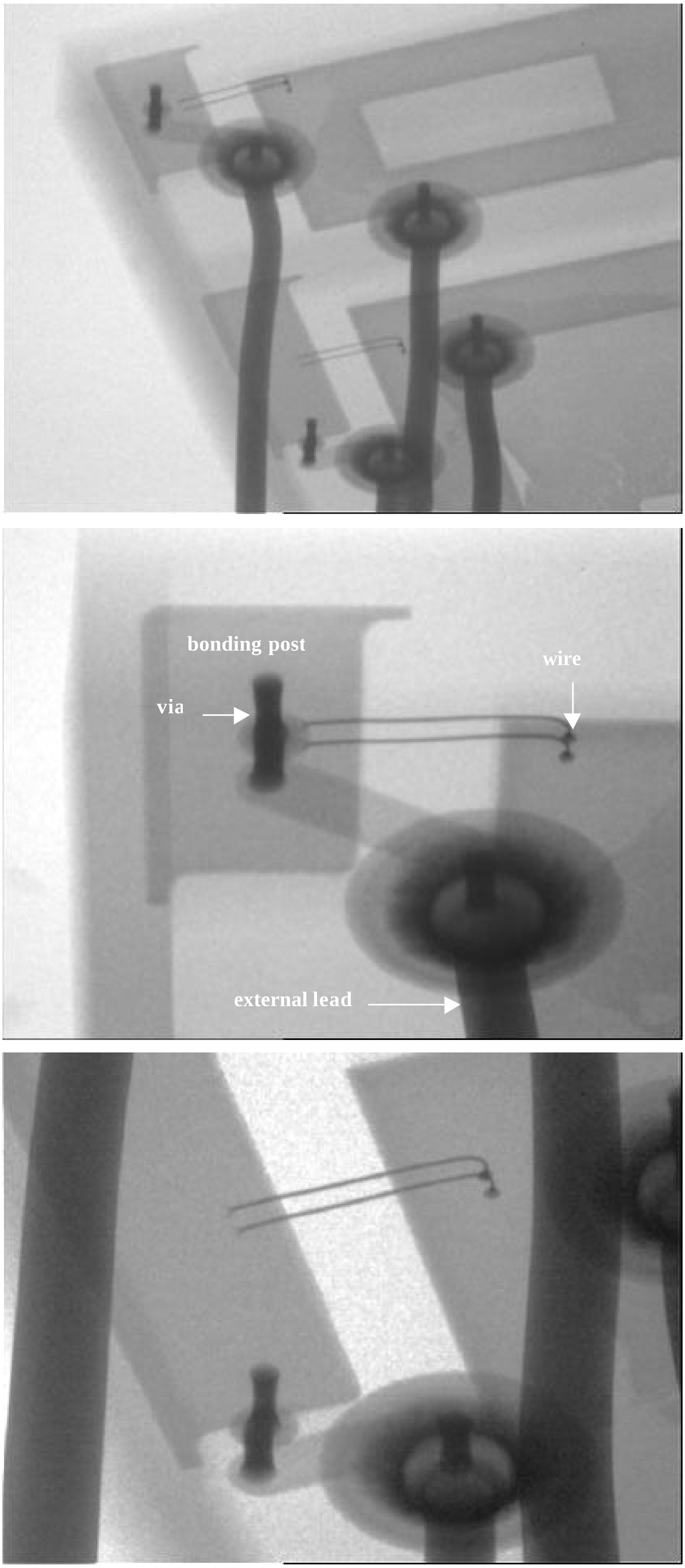
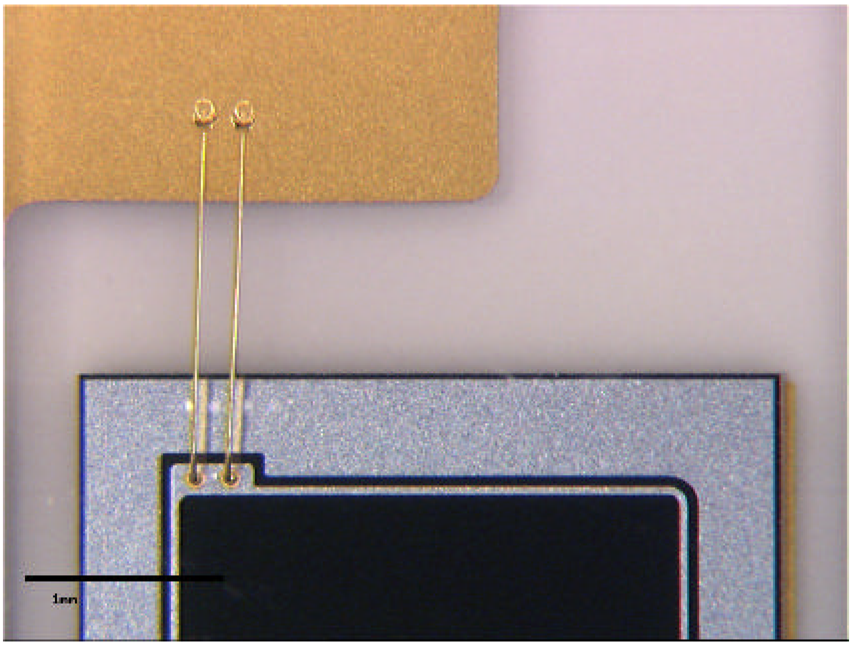


Figure 4. Tilted X-rays views of the internal connections.



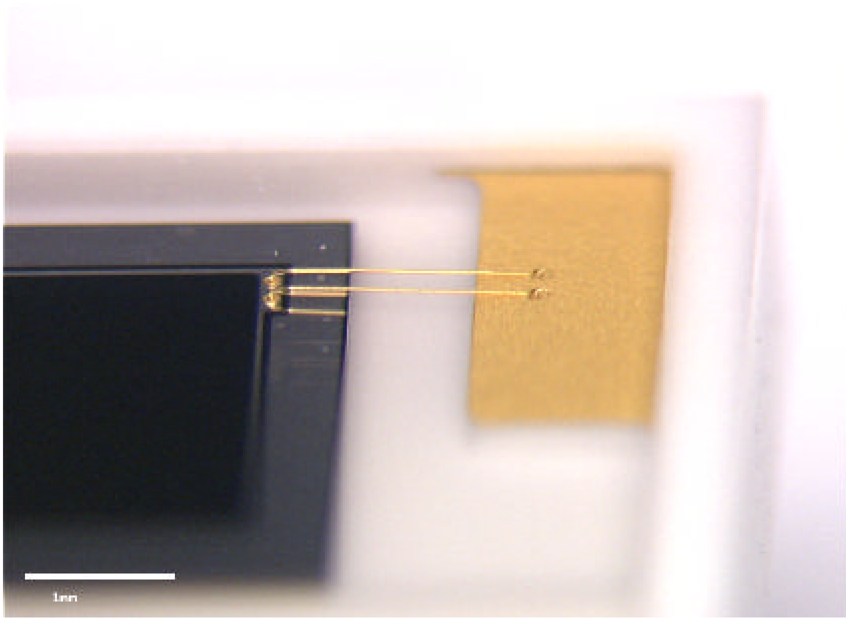
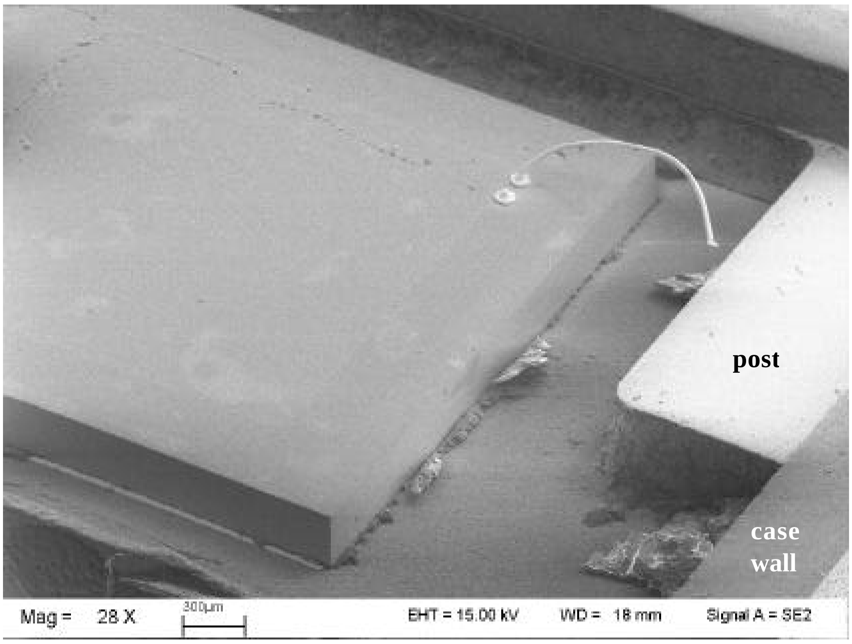
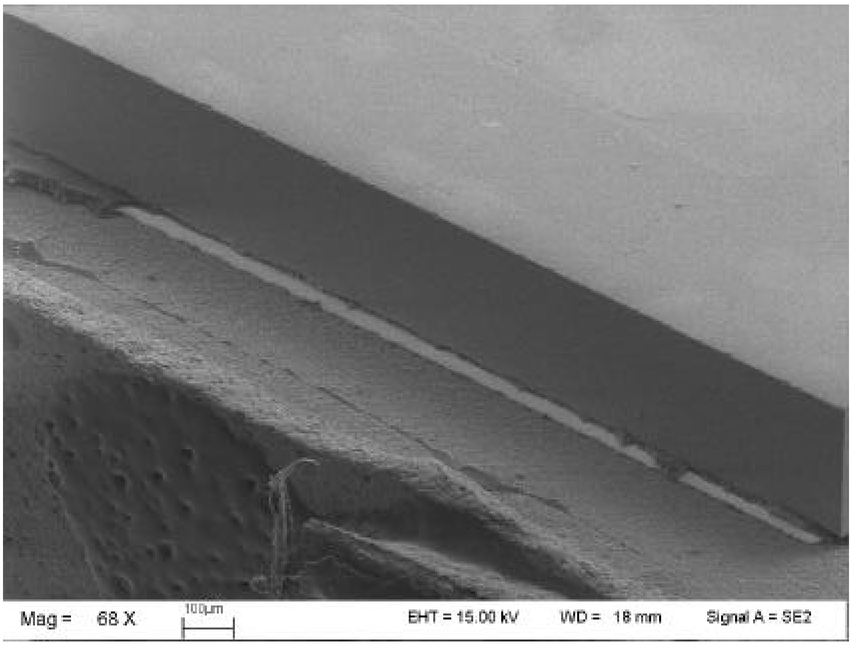


Figure 5. Details of the bonding wires through the clear resin.
Top : mag ≈28X ; bottom : mag 22X.





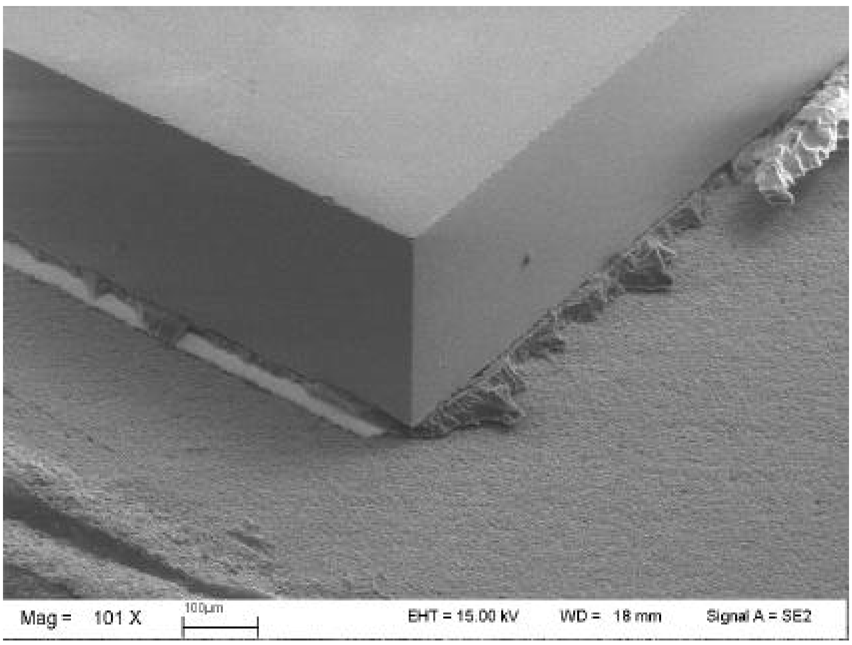
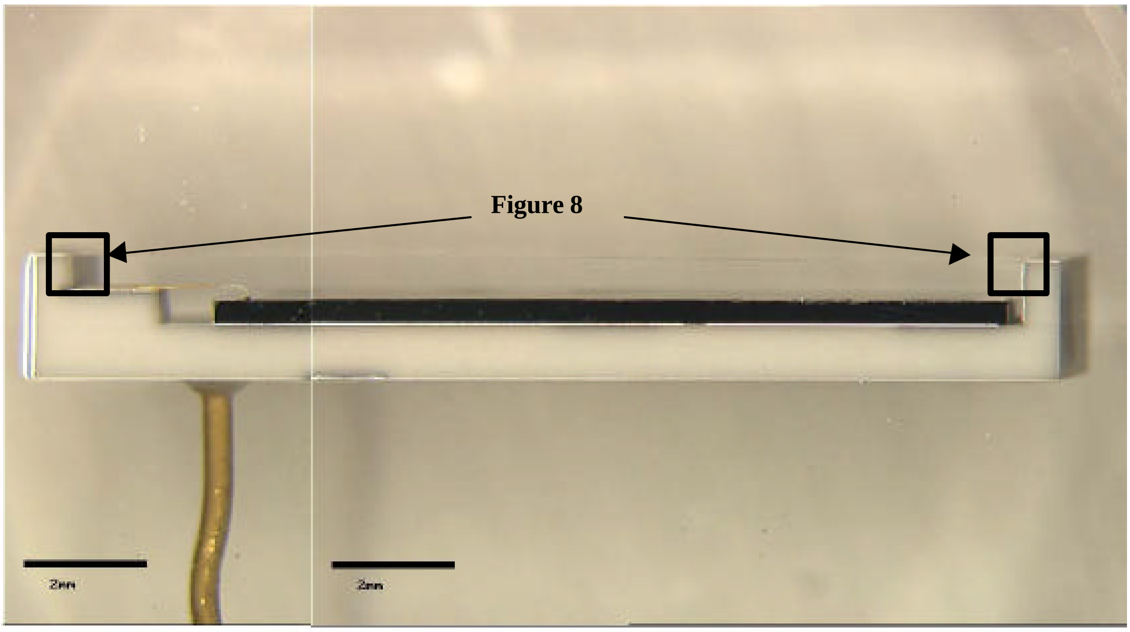
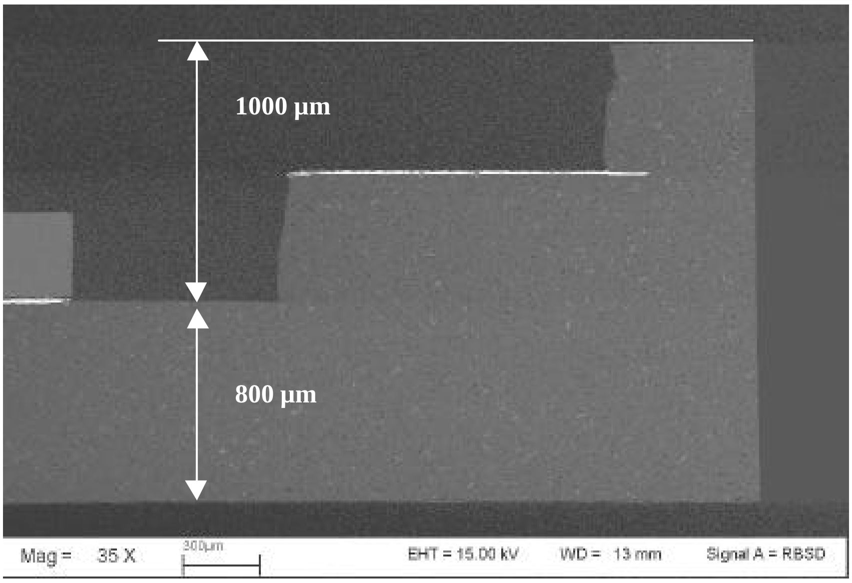


Figure 6. SEM details of die A assembly and dicing.
Top : mag 28X ; center : mag 68X ; bottom : mag 101X.





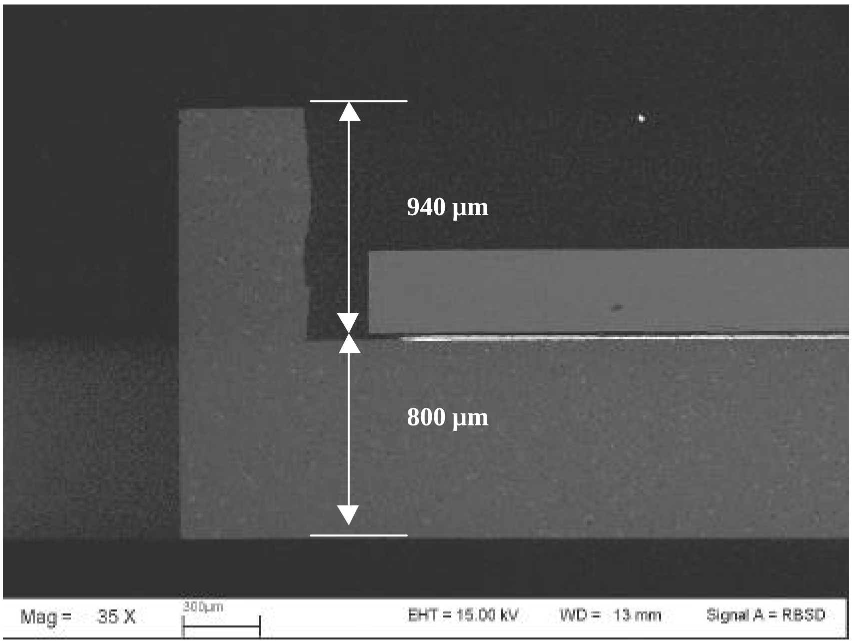
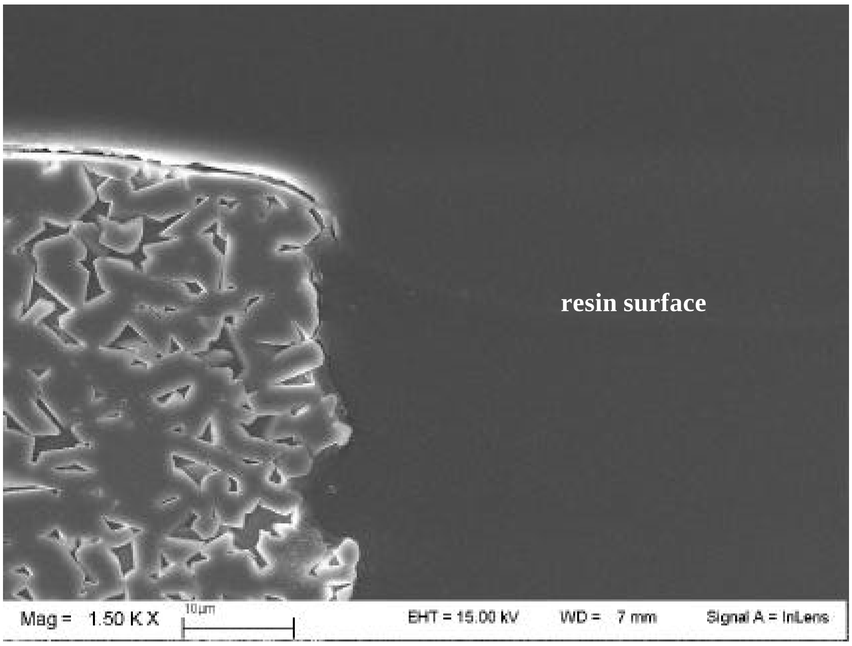


Figure 7. Optical and SEM views in section of the package.
Top : mag ≈9X ; center and bottom : mag 35X.



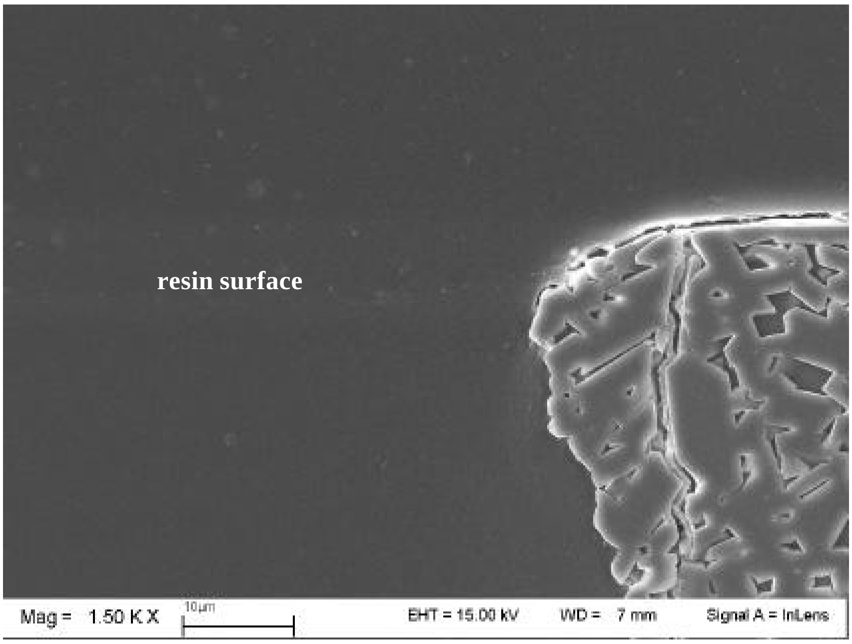
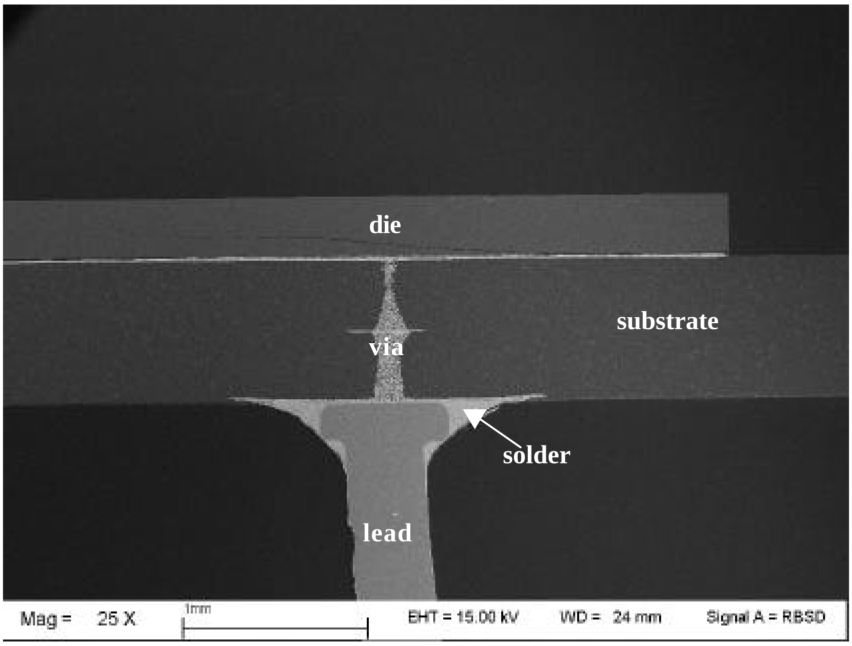


Figure 8. SEM views showing the clear resin surface compared to the ceramic wall surface, mag 1500X.



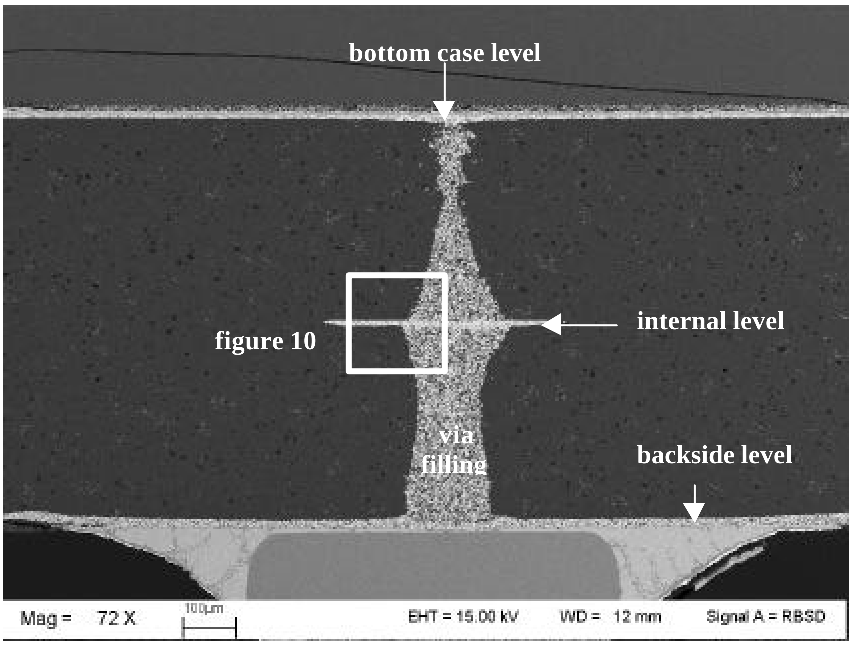
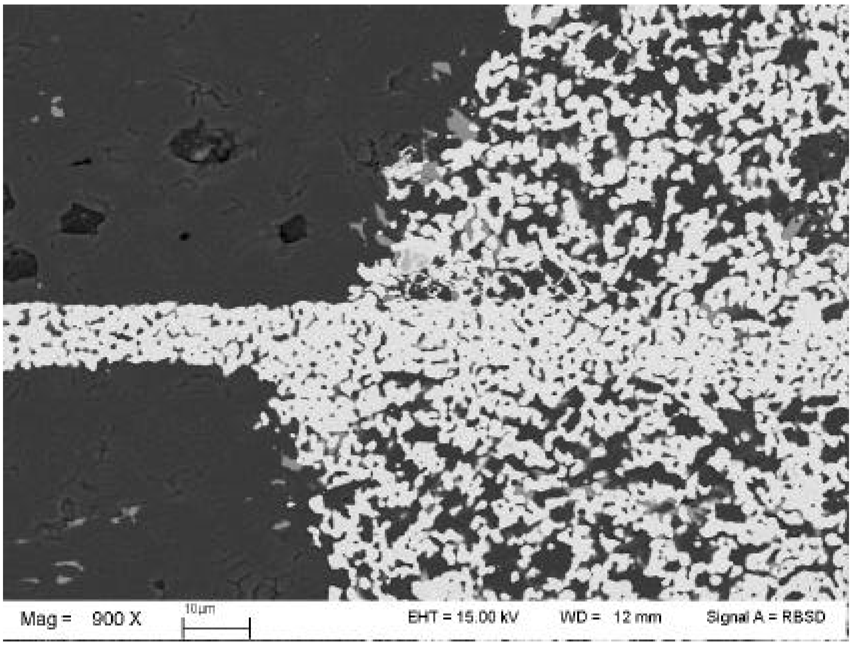


Figure 9. SEM views in section of internal via connection.
Top : mag 25X ; bottom : mag 72X.



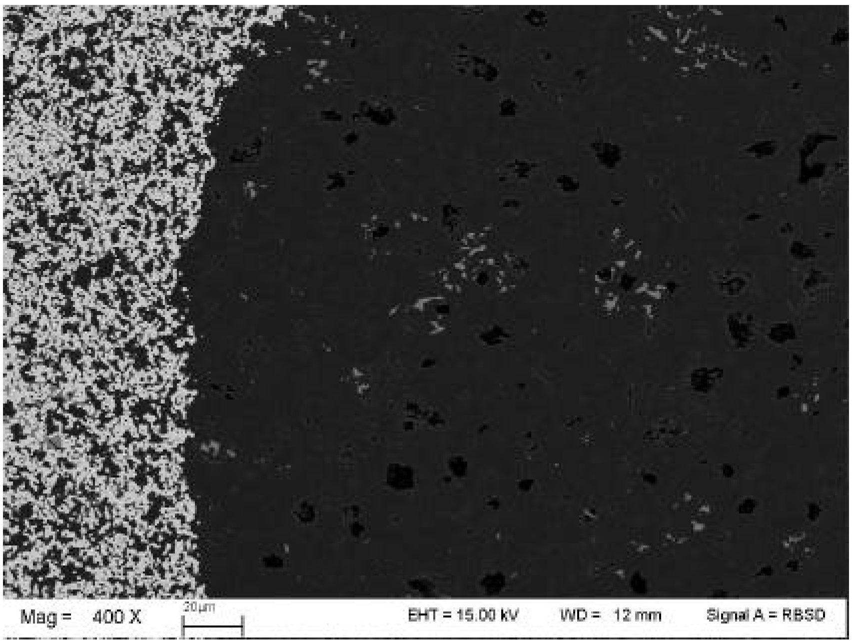


Figure 10. SEM views of internal layer, ceramic and via filling.
Top : mag 900X ; bottom : mag 400X.

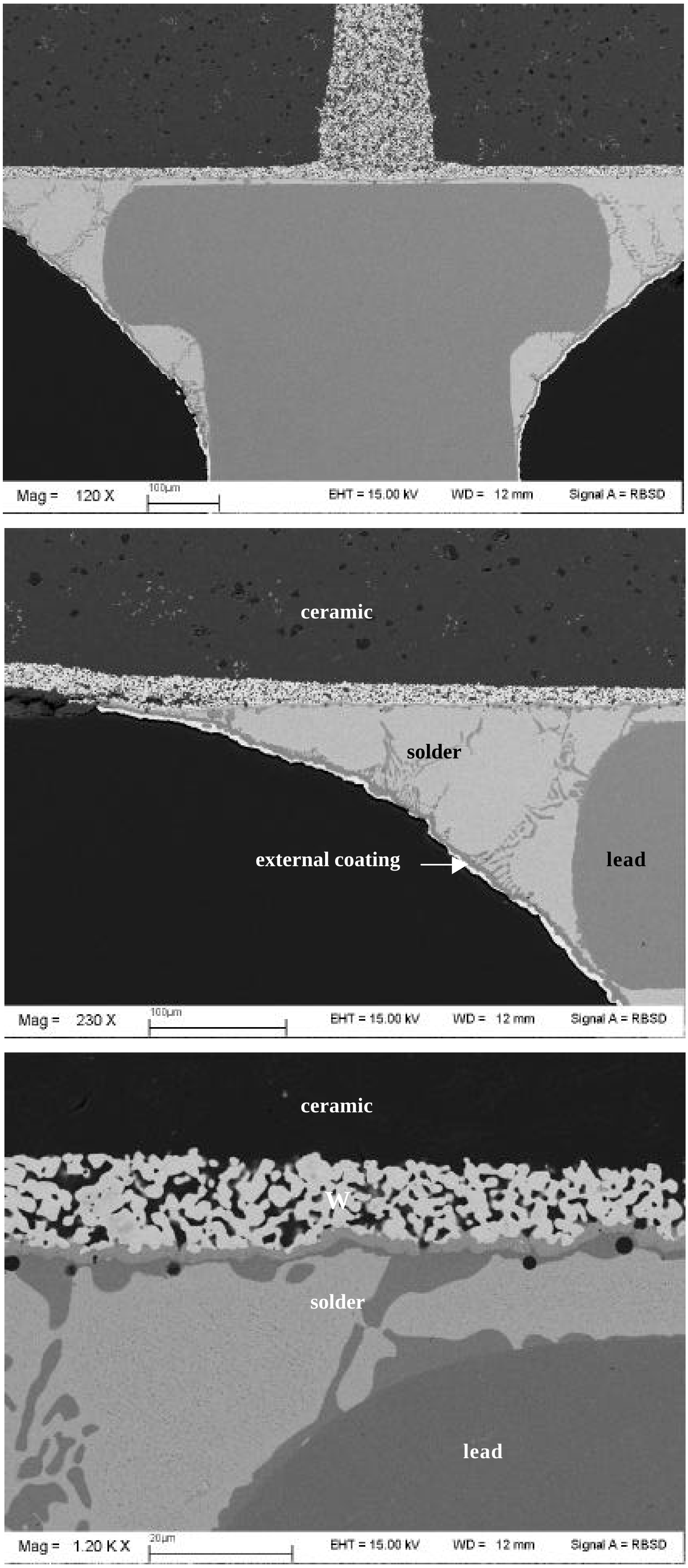
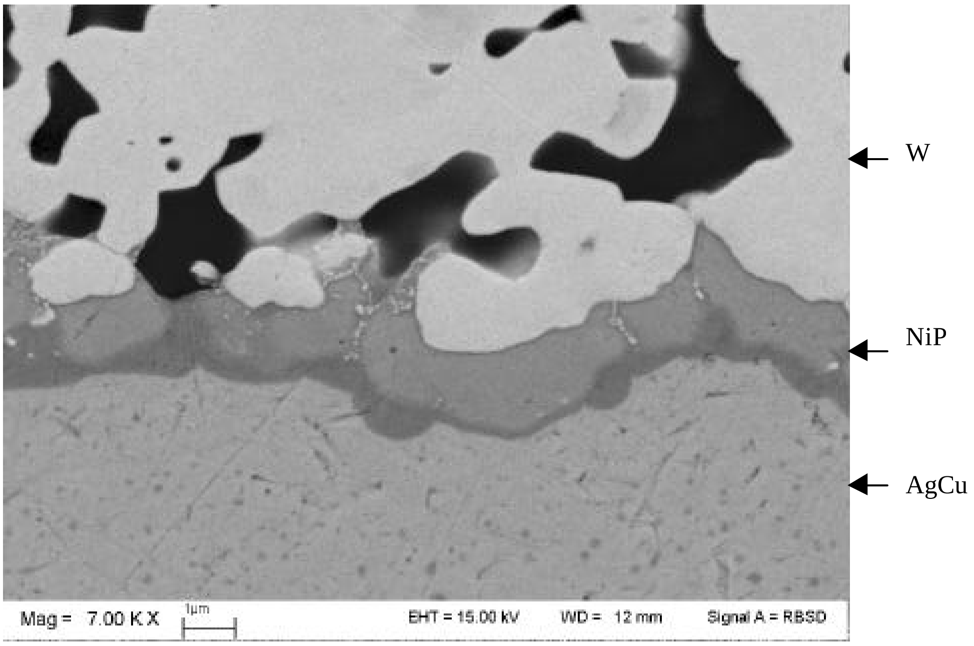


Figure 11. Details of lead soldering.
Top : mag 120X ; center : mag 230X ; bottom : mag 1200X.



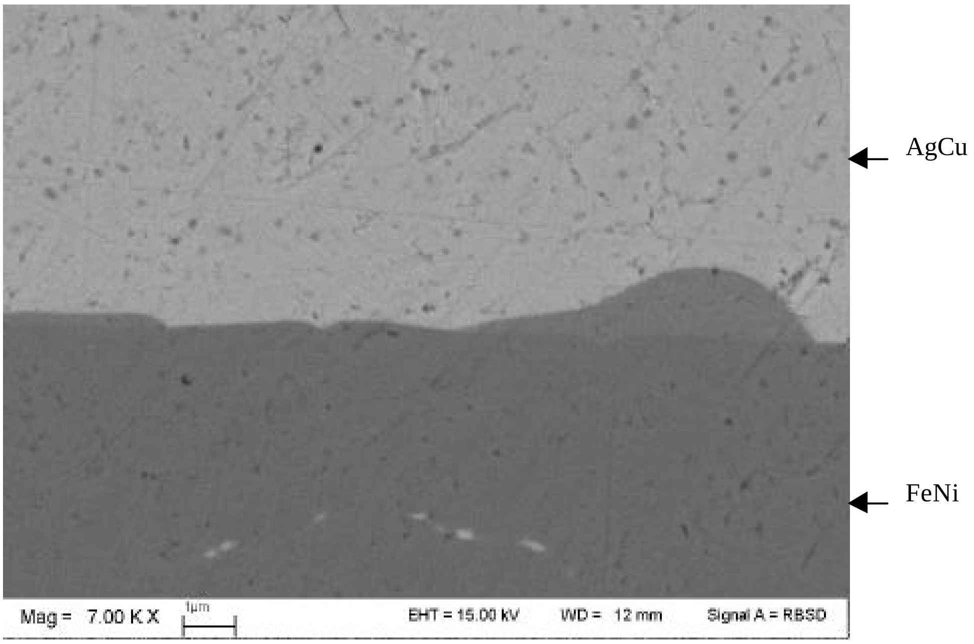
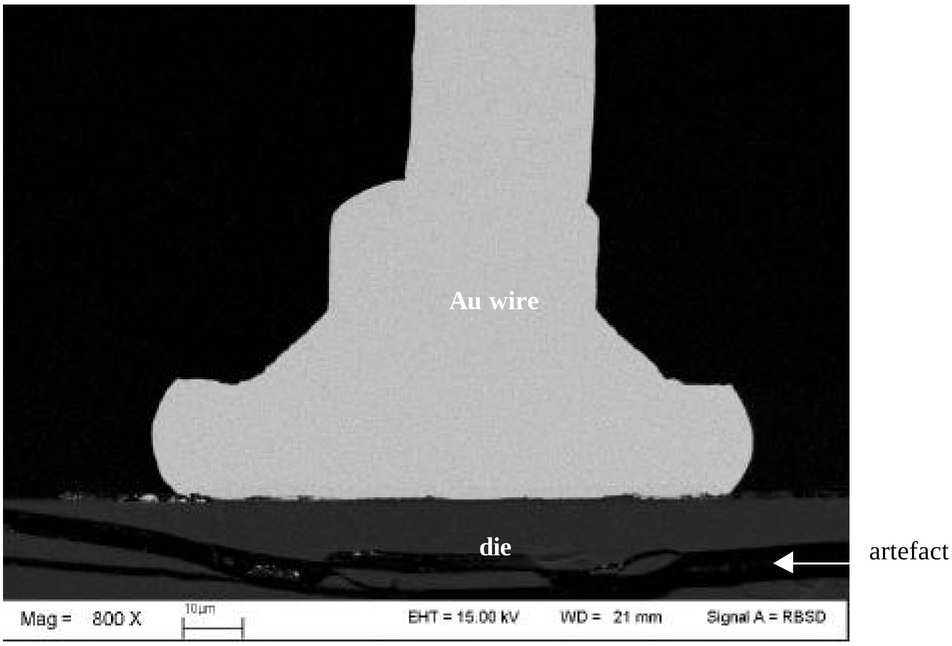


Figure 12. SEM details of lead soldering, mag 7000X.



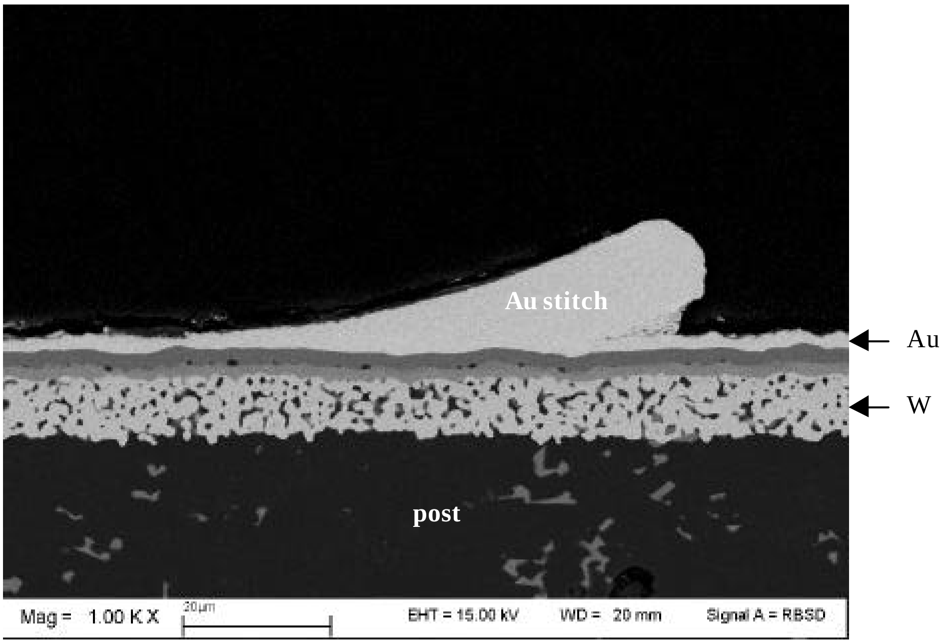
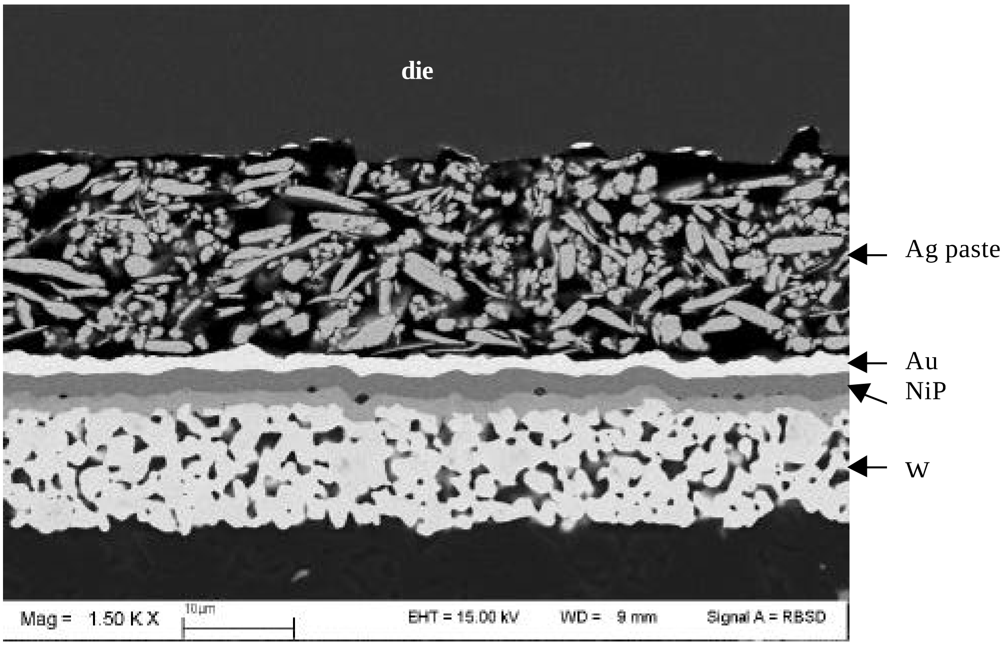


Figure 13. SEM details in section of ball and stitch bond.
Top : mag 800X ; bottom : mag 1000X.



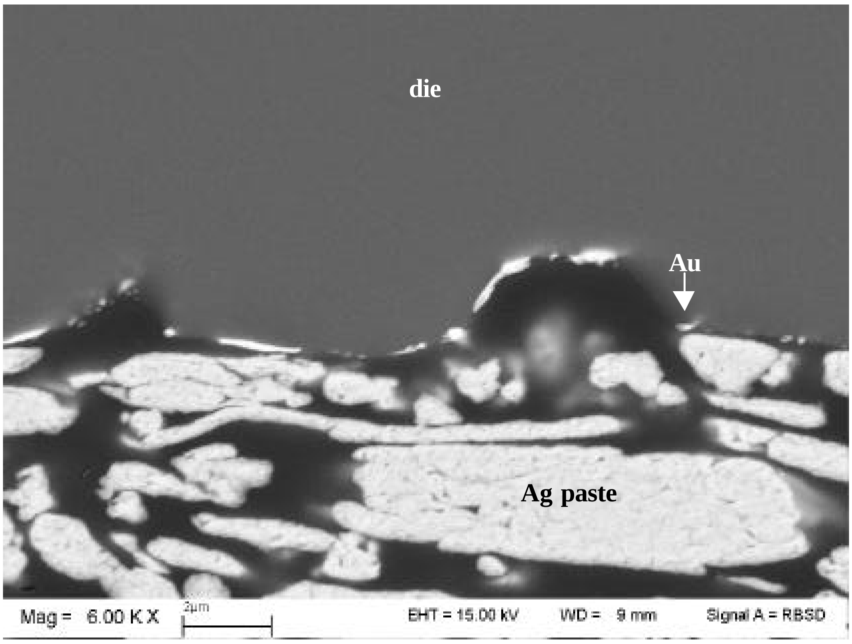
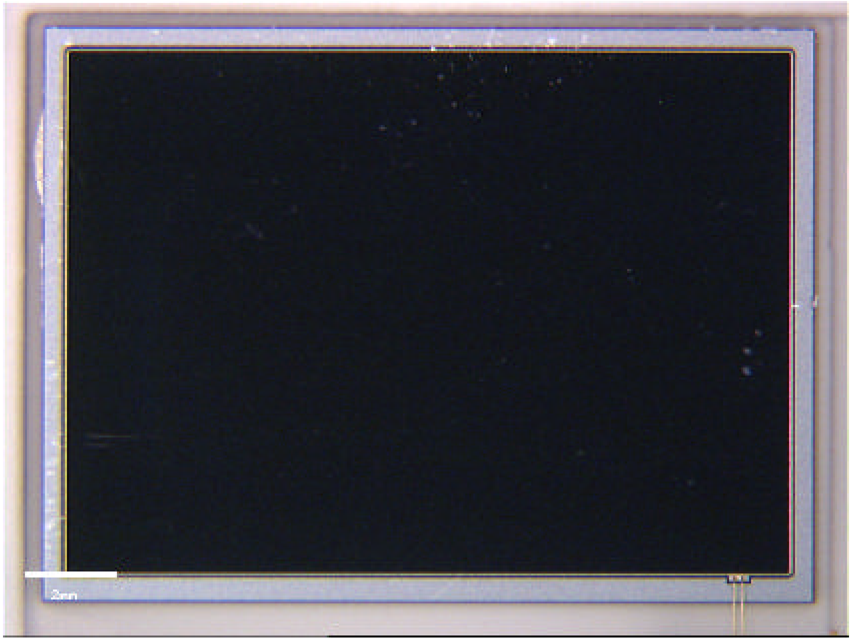


Figure 14. SEM views in section of die attach material and die backside metallization.
Top : mag 1500X ; bottom : mag 6000X.



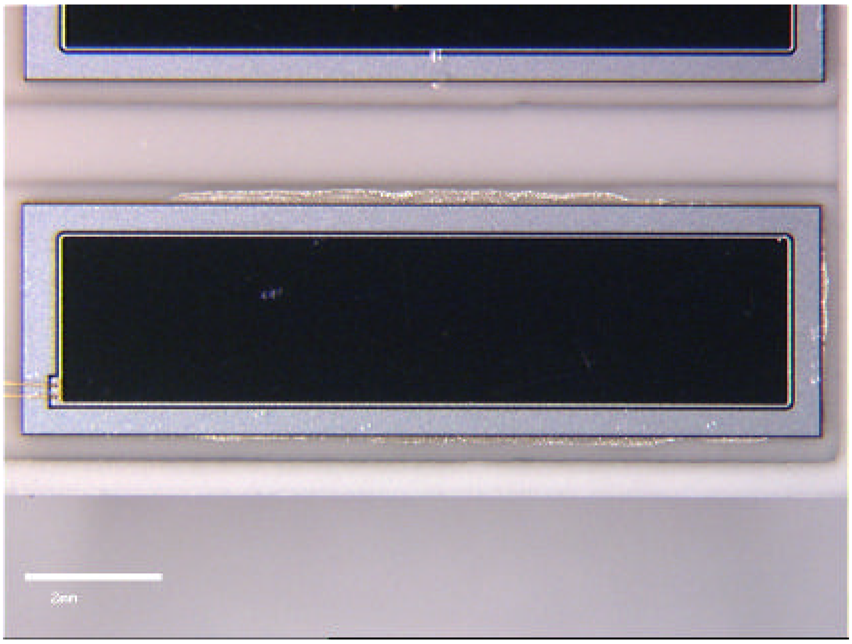


Figure 15. General views of the dice.
Top : mag ≈7X ; bottom : mag ≈10X.

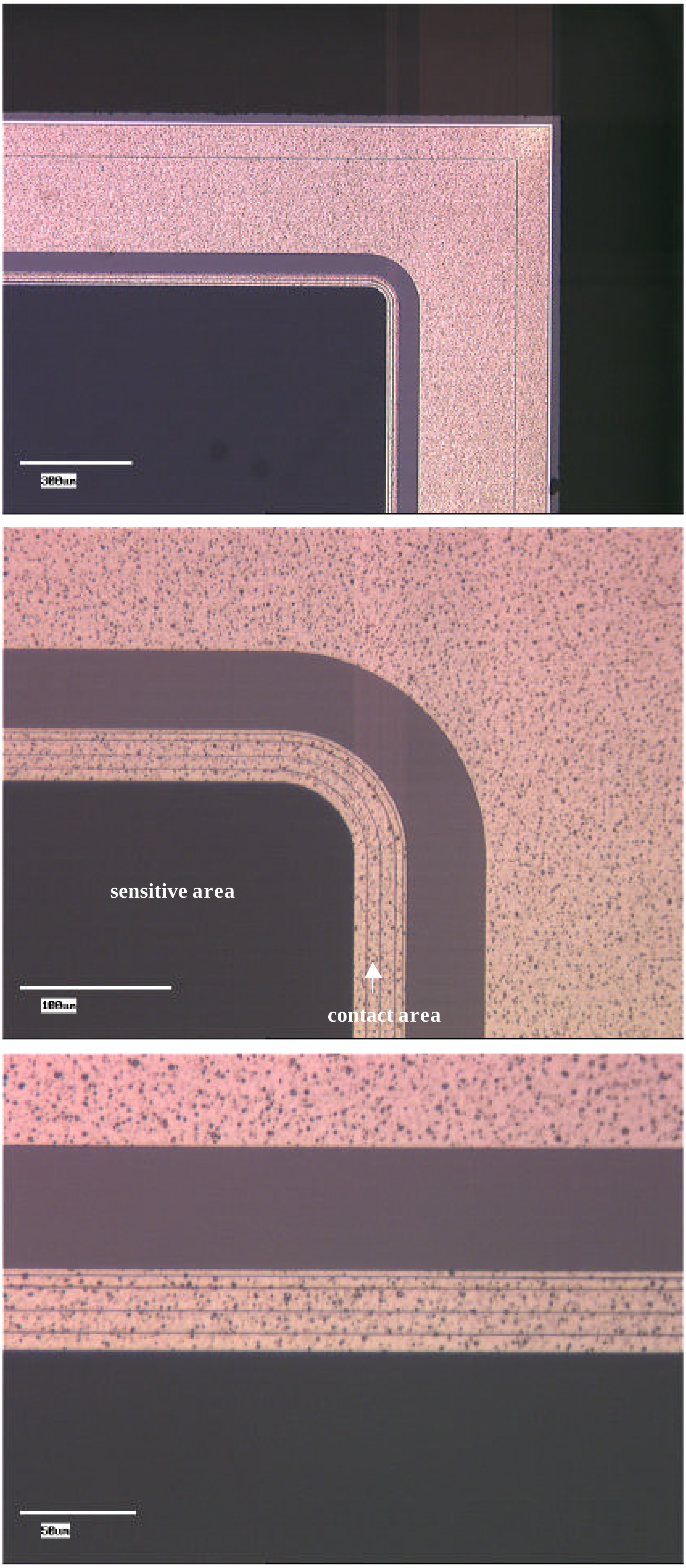


Figure 16. Optical details of the die metallization.
Top : mag 59.3X ; center : mag 239X ; bottom : mag 373X.

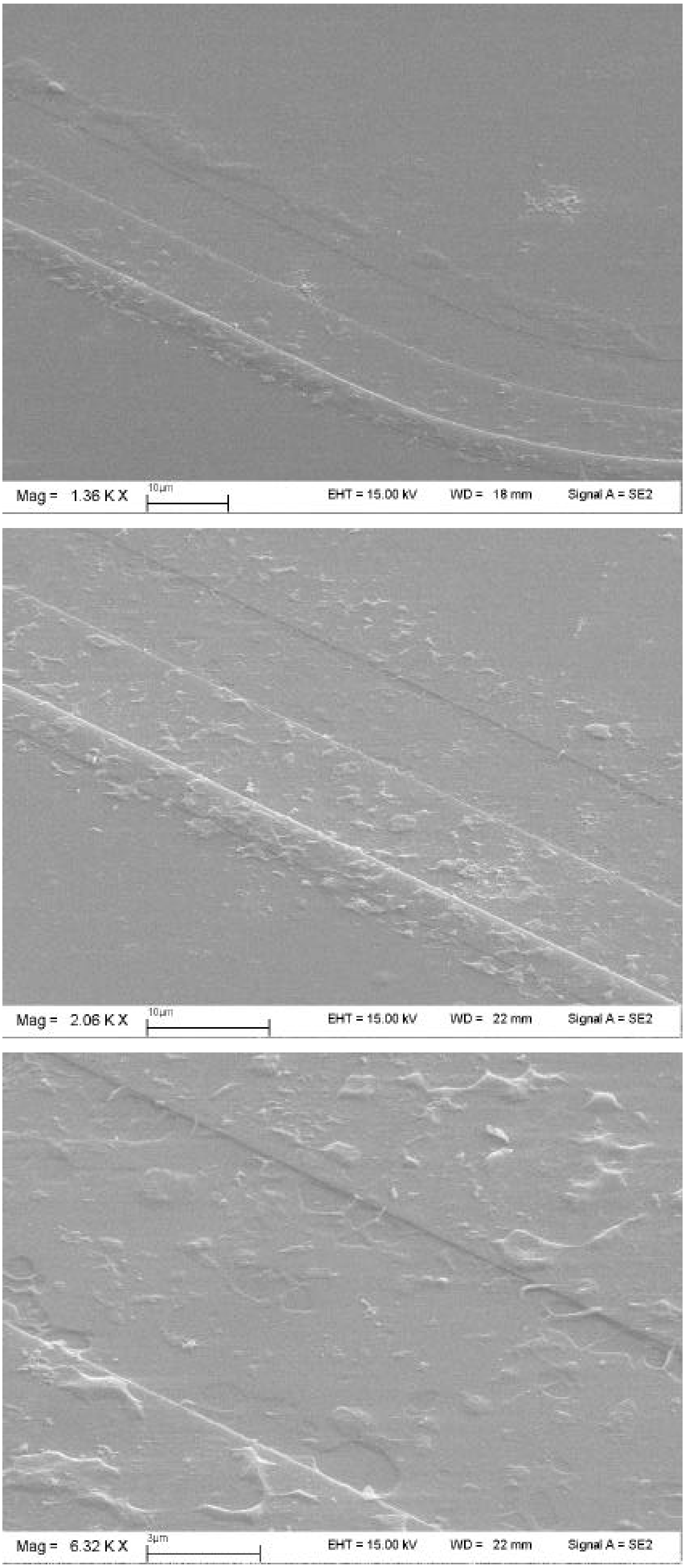
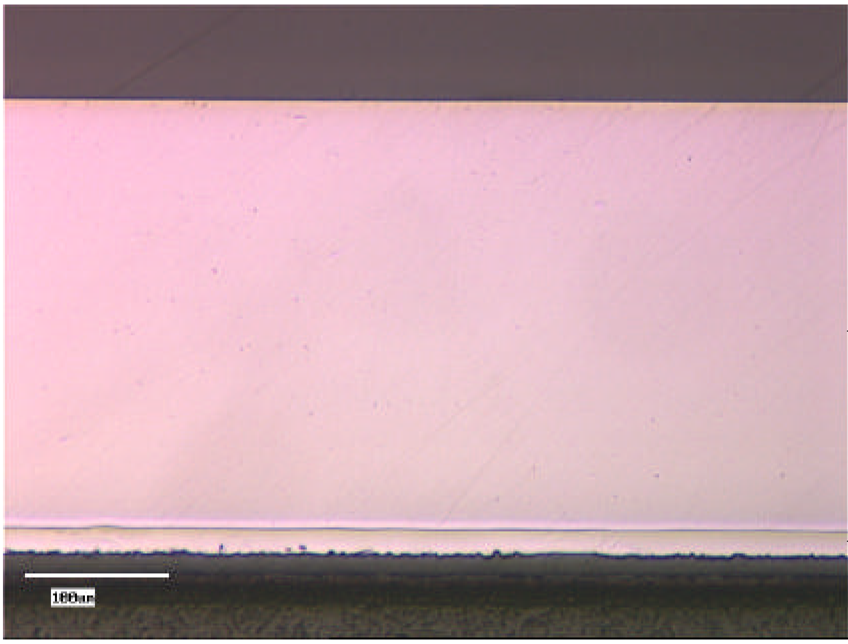
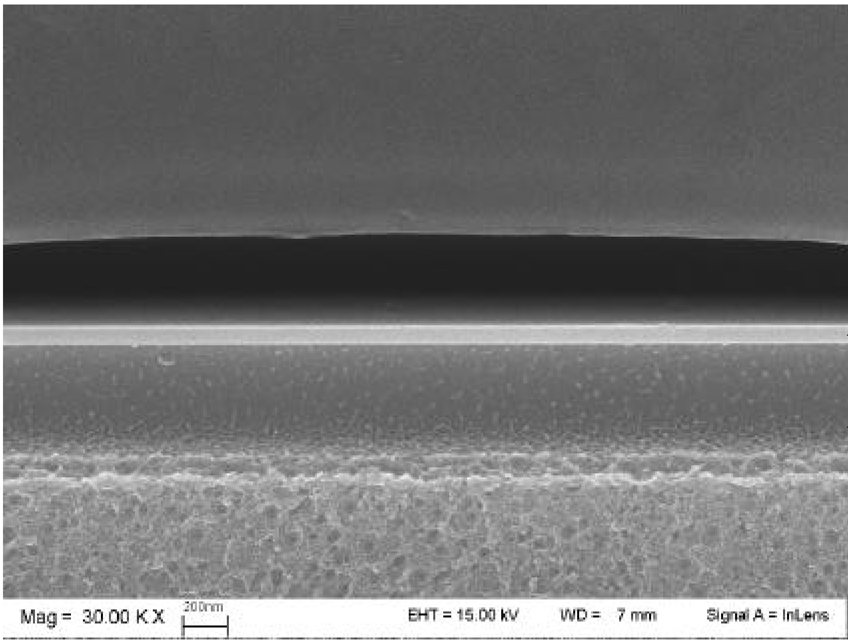


Figure 17. SEM details of aluminum to substrate contact area.
Top : mag 1360X ; center : mag 2060X ; bottom : mag 6320X.





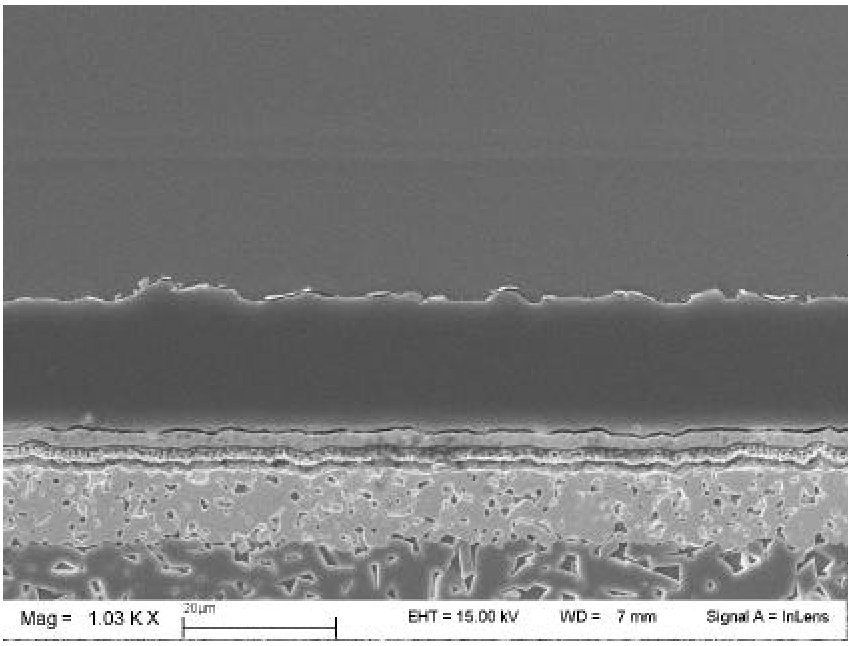
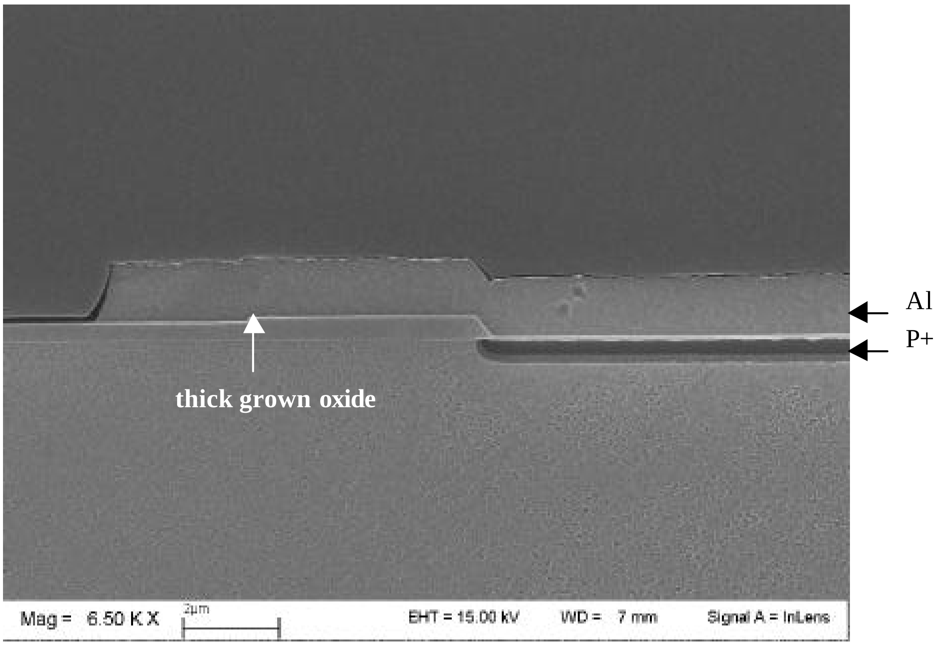


Figure 18. Optical and SEM views of diffusions.
Top : mag 186X ; center : mag 30000X ; bottom : mag 1030X.



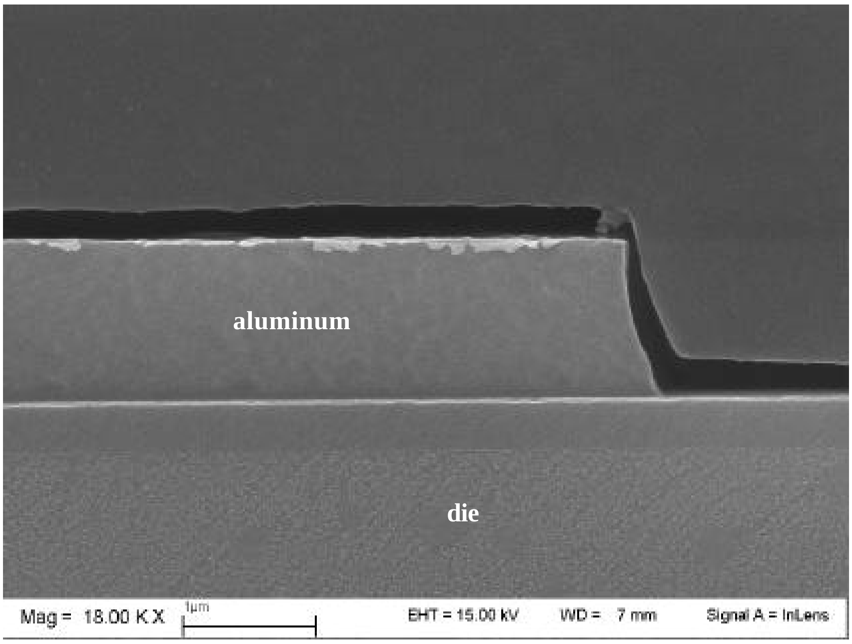


Figure 19. SEM views of metal layer.
Top : mag 6500X ; bottom : mag 18000X.

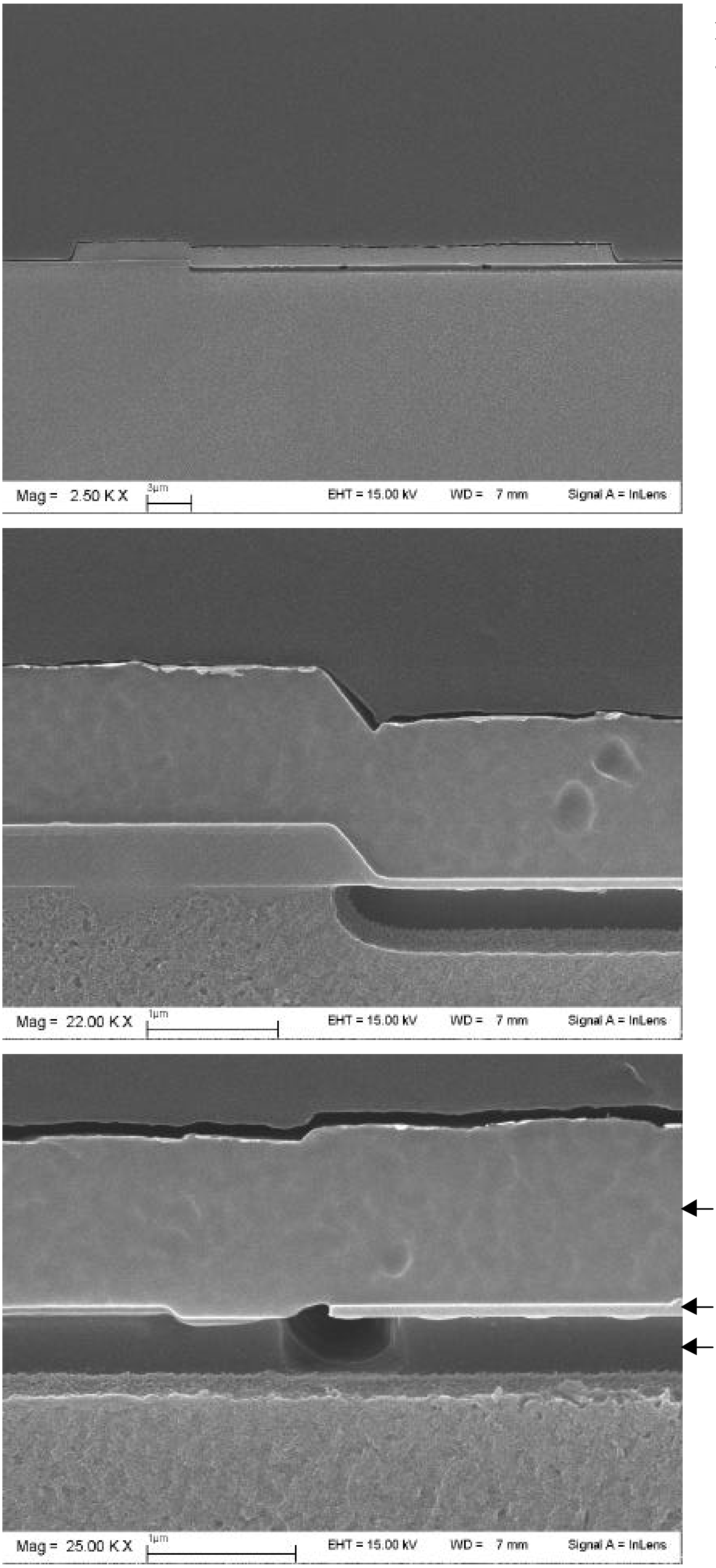


Figure 20. SEM views in section of metal to substrate contact area.
Top : mag 2500X ; center : mag 22000X ; bottom : mag 25000X.

SERMA TECHNOLOGIES

ACOUSTIC MICROSCOPY INSPECTION
ON DPD-S8576 FROM HAMAMATSU
REPORT E01P1435/02 – JUNE, 2002

This analysis was performed for :

CEA
Orme des Merisiers
Bâtiment 709
91191 GIF-SUR-YVETTE

Performed by : M. AUDE

Approved by : J.M ETCHARREN

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S.A. à Directoire et Conseil de Surveillance au capital de 2.301.072 € - SIRET 380 712 828 00058 – CODE APE 731 Z

INTRODUCTION

Photodiodes (DPD-S8576) from HAMAMATSU were submitted to SERMA Technologies for package integrity and die-attach analysis by acoustic microscopy

The acoustic microscopy was performed at samples reception (T_0) and all along the reliability tests (temperature and humidity test, temperature cycling tests, low and high temperature storage).

CONCLUSION

* At initial acoustic microscopy (T_0) on the 22 parts, no delamination at epoxy / die and epoxy / ceramic interfaces was detected. However, some voids are present in die-attach.

* After temperature and humidity stress tests, on the 4 parts observed (96, 115, 121, 187), no delamination at epoxy / die and epoxy / ceramic interfaces was detected. There is no evolution of die-attach interface.

* All along the temperature cycling stress tests, 15 parts were observed and some defects were detected :
  - delamination at epoxy / die on 3 parts (108, 109, 126) and cracks in epoxy on 2 parts (109, 126)
  - delamination at epoxy / ceramic interfaces on 6 parts (107, 108, 110, 109, 120, 124)
  - beginning of delamination at epoxy / ceramic interface on 2 parts (122, 123)
  - there is no evolution of die-attach interface :
    note : on Part 126 after TC-30°C, 180°C, the die attach cannot be observed due to the delamination at epoxy/die interface.

* After 168 hours storage at –40°C, on the 3 parts observed (104, 116, 122, already analysed during thermal cycling) one part (122) was found with cracks in epoxy and partial delamination at epoxy / ceramic interfaces and epoxy / die. There is no evolution on the other parts. No observation was done at die attach interface.

* After 168 hours storage at 90°C, on the 3 parts observed (105, 117, 123 already analysed during thermal cycling) no delamination evolution was detected, only part 123 show a beginning of delamination at epoxy / ceramic interface. No observation was done at die attach interface.

PROCEDURE

X epoxy/die and epoxy/ceramic analysis
O die attach observation

Parts	96	104	105	106	107	108	109	110	111	112	114	115	116	117	118	120	121	122	123	124	126	187
Acoustic microscopy at T0	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O
Acoustic microscopy after TH30°C/60% RH	X O											X O										
Acoustic microscopy after TH50°C/90% RH																	X O					X O
Acoustic microscopy TC 0°/50°C		X O											X O					X O				
Acoustic microscopy after TC -10°C/60°C			X O											X O					X O			
Acoustic microscopy after TC -20°C/70°C				X O											X O					X O		
Acoustic microscopy after TC -30°C/80°C					X O											X O					X O	
Acoustic microscopy after TC -40°C/90°C						X	X	X														
Acoustic microscopy after 168 hours at -40°C		X											X					X				
Acoustic microscopy after 168 hours at 90°C			X											X					X			

ACOUSTIC MICROSCOPY

1-NOTICE

Principle:
The image is formed by the componant scanning by an acoustic transducer, the reflected part of the signal at each crossed interface is used to form the image point by point.
If air is founded, the reflected signal is inverted which is traduced by a red or a yellow point on the image.

Interpretation:
All red or yellow area is an area which was interpreted as delaminated by the computer algorithm: this is true in the most of case. However, combination of material or structure (fiber, particle…) can induce the same red image without delamination.
This acoustic image in phase inversion must be studied with the acoustic operator comments and not as an absolute information.

2-EQUIPMENT

SONIX Acoustic microscope
Soft SONIX IC LAB/IC PRO Version 4.0 Release 4.01.
Transducer: 75MHz

Acoustic microscopy analysis can detect delaminations at various interfaces:

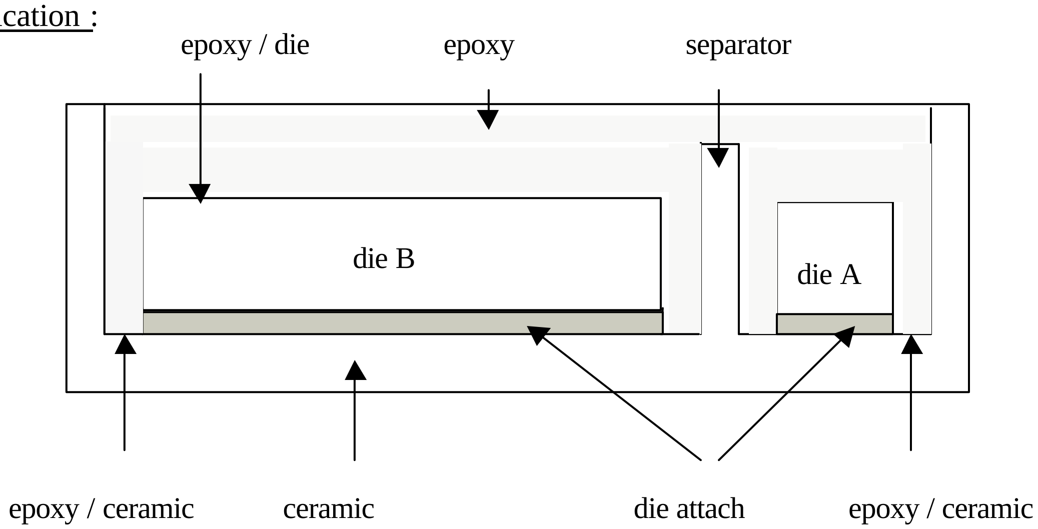
- Epoxy/die
- Epoxy/ceramic
- die attach interface

Procédures et références :

- IPC/JEDEC J-STD-035
Acoustic microscopy for non hermetic
Encapsulated Electronics components

- Instruction SERMA :
ILAB033 du 18/09/2000
Analyse par microscopie acoustique

Interfaces identification :



3-RESULTS

Top scanning : focus was performed at epoxy/die interface and die-attach interface.
On delamination image (epoxy/die and epoxy/ ceramic observations), delaminated areas are outlined in red or in yellow.
On amplitude image (die-attach observation), areas with a lack of die attach or lack of adhesion are white. In this case, due to componant structure, delamination image cannot be taken in account.
Results are given in the following tables :

INITIAL: parts at T_0. (figures 1 to 8)

Top Scanning	DELAMINATION AT INTERFACE	
Part reference (image ref.)	epoxy/die	epoxy/ceramic
N°96 (1435T96/1435D96)	No	No
N°104 (1435T104/1435D104)	No	No
N°105 (1435T105/1435D105)	No	No
N°106 (1435T106/1435D106)	No	No
N°107 (1435T107/1435D107)	No	No
N°108 (1435T108/1435D108)	No	No
N°109 (1435T109/1435D109)	No	No
N°110 (1435T110/1435D110)	No	No
N°111 (1435T111/1435D111)	No	No
N°112 (1435T112/1435D112)	No	No
N°114 (1435T114/1435D114)	No	No
N°115 (1435T115/1435D115)	No	No
N°116 (1435T116/1435D116)	No	No
N°117 (1435T117/1435D117)	No	No
N°118 (1435T118/1435D118)	No	No
N°120 (1435T120/1435D120)	No	No
N°121 (1435T121/1435D121)	No	No
N°122 (1435T122/1435D122)	No	No
N°123 (1435T123/1435D123)	No	No
N°124 (1435T124/1435D124)	No	No
N°126 (1435T126/1435D126)	No	No
N°187 (1435T187/1435D187)	No	No

On all the parts, voids were observed in the die attach (white areas on amplitude image).

TEMPERATURE AND HUMIDITY (figures 9 and 10)

30°C/ 60% RH

Top Scanning	DELAMINATION AT INTERFACE	
Part reference (image ref.)	epoxy/die	epoxy/ ceramic
N°96 (1435H96/1435P96)	No	No
N°115 (1435H115/1435P115)	No	No

50°C/ 90% RH

Top Scanning	DELAMINATION AT INTERFACE	
Part reference (image ref.)	epoxy/die	epoxy/ ceramic
N°121 (1435H121/1435P121)	No	No
N°187 (1435H187/1435PD187)	No	No

No die-attach voiding increase was noticed after temperature and humidity stress, Figure 10.

THERMAL CYCLING

0°C/ 50°C (figure 11)

Top Scanning	DELAMINATION AT INTERFACE	
Part reference (image ref.)	epoxy/die	epoxy/ ceramic
N°104 (1435C104/1435B104)	No	No
N°116 (1435C116/1435B116)	No	No
N°122 (1435C122/1435B122)	No	Beginning of delamination between die and separator

-10°C/ 60°C (figure 12)

Top Scanning	DELAMINATION AT INTERFACE	
Part reference (image ref.)	epoxy/die	epoxy/ ceramic
N°105 (1435C105/1435B105)	No	No
N°117 (1435C117/1435B117)	No	No
N°123 (1435C123/1435B123)	No	Beginning of delamination between die and separator

-20°C/ 70°C (figure 13)

Top Scanning	DELAMINATION AT INTERFACE	
Part reference (image ref.)	epoxy/die	epoxy/ ceramic
N°106 (1435C106/1435B106)	No	No
N°118 (1435C118/1435B118)	No	No
N°124 (1435C124/1435B124)	No	Partial

-30°C/ 80°C (figure 14)

Top Scanning	DELAMINATION AT INTERFACE	
Part reference (image ref.)	epoxy/die	epoxy/ ceramic
N°107 (1435C107/1435B107)	No	Partial
N°120 (1435C120/1435B120)	No	Partial
N°126 (1435C126/1435B126)	Complete	Partial

No die-attach voiding increases after stress was noticed on all the parts (die attach cannot be observed on #126 due to delamination on the die).

-40°C/ 90°C (figure 15)

Top Scanning	DELAMINATION AT INTERFACE	
Part reference (image ref.)	epoxy/die	epoxy/ ceramic
N°108 (1435V108)	Partial	Partial
N°109 (1435R109)	Partial 80% + cracks in epoxy	Partial
N°110 (1435R110)	No	Partial

-40°C/ 168 hours (figure 16)

Top Scanning	DELAMINATION AT INTERFACE	
Part reference (image ref.)	epoxy/die	epoxy/ ceramic
N°104 (1435R104)	No	No
N°116 (1435V116)	No	No
N°122 (1435R122)	Partial + cracks in epoxy: the delaminated area size is minimized by the presence of water in the diode package.	Partial

90°C/ 168 hours (figure 17)

Top Scanning	DELAMINATION AT INTERFACE	
Part reference (image ref.)	epoxy/die	epoxy/ ceramic
N°105 (1435R105)	No	No
N°117 (1435R117)	No	No
N°123 (1435V123)	No	Beginning of delamination between die and separator

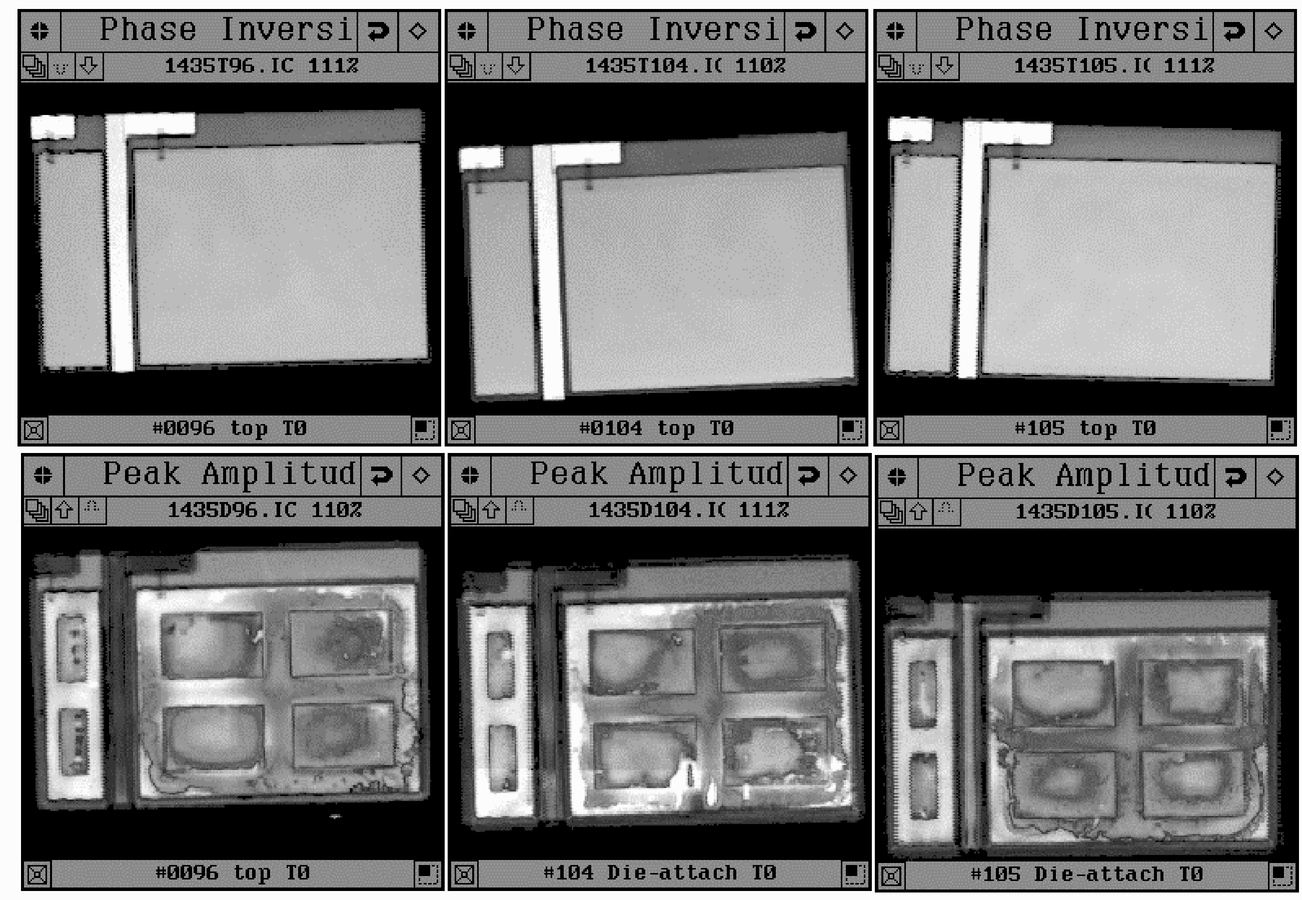


Figure 1. Acoustic microscopy, parts 96, 104 and 105 ; Initial.
Top : delamination image ; epoxy / die, epoxy / ceramic.
Bottom : amplitude image, die-attach interface.

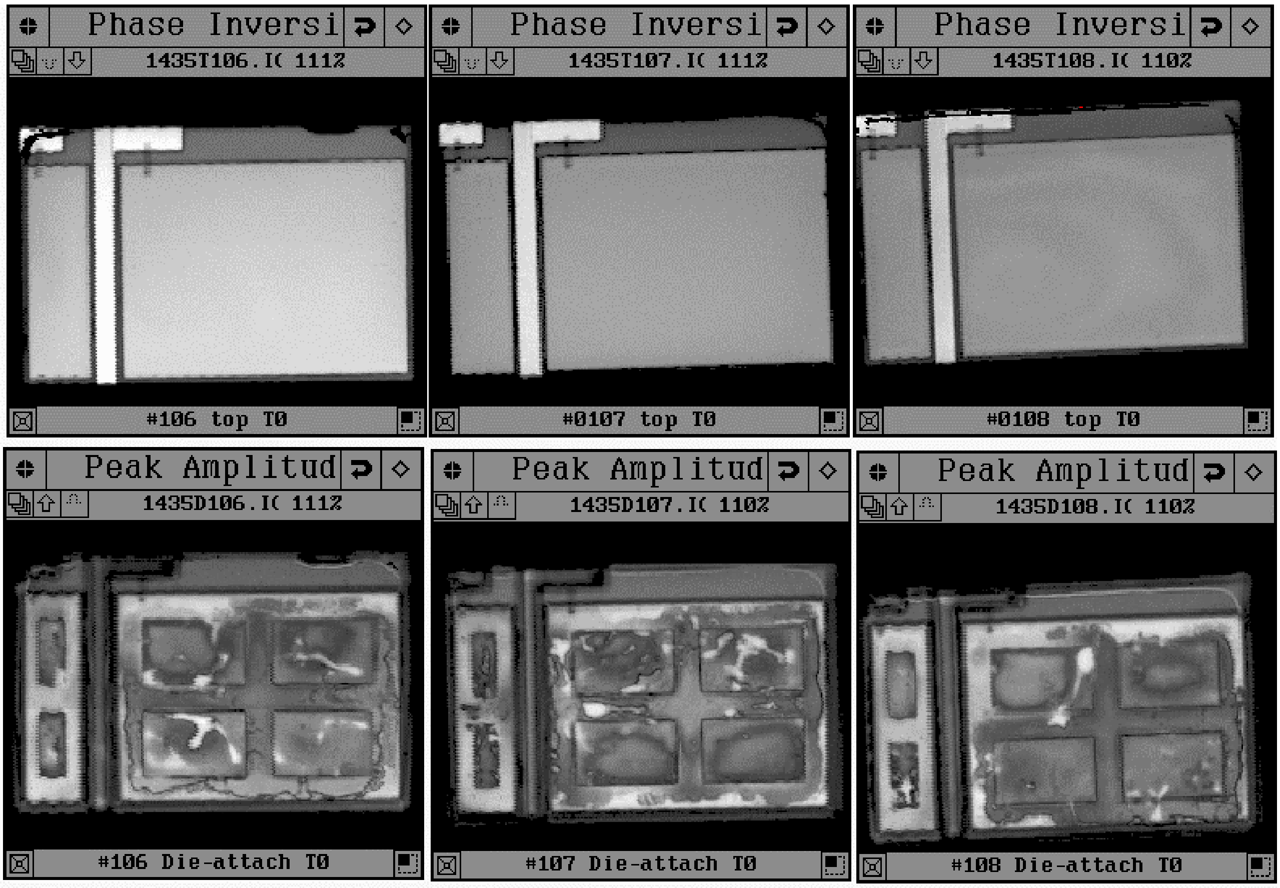


Figure 2. Acoustic microscopy, parts 106 to 108 ; Initial.
Top : delamination image ; epoxy / die, epoxy / ceramic.
Bottom : amplitude image, die-attach interface.

Figure 3. Acoustic microscopy, parts 109 to 111 ; Initial.
Top : delamination image ; epoxy / die, epoxy / ceramic.
Bottom : amplitude image, die-attach interface.

Figure 4. Acoustic microscopy, parts 112, 114 and 115 ; Initial.
Top : delamination image ; epoxy / die, epoxy / ceramic.
Bottom : amplitude image, die-attach interface.

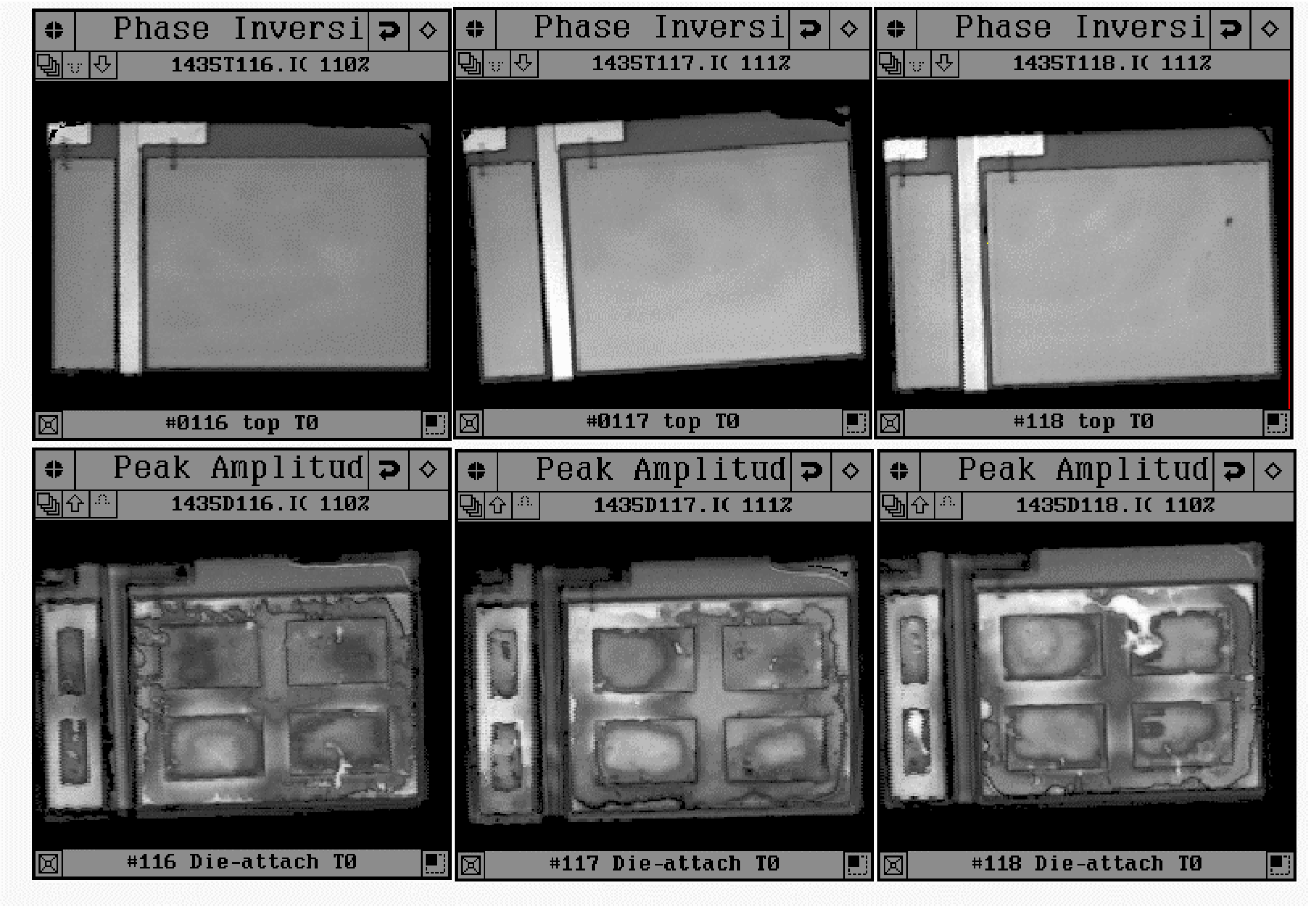


Figure 5. Acoustic microscopy, parts 116 to 118 ; Initial.
Top : delamination image ; epoxy / die, epoxy / ceramic.
Bottom : amplitude image, die-attach interface.

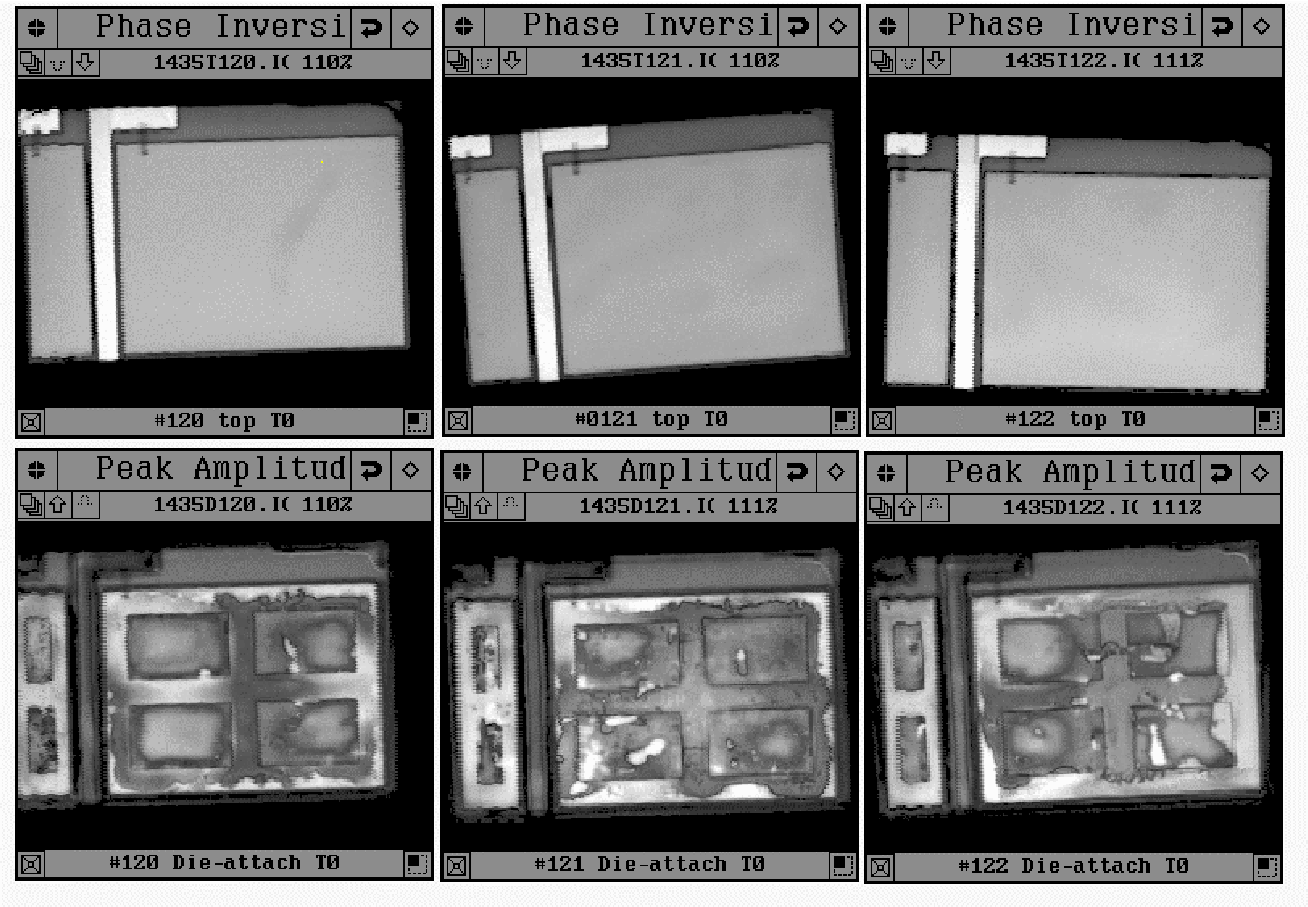


Figure 6. Acoustic microscopy, parts 120 to 122 ; Initial.
Top : delamination image ; epoxy / die, epoxy / ceramic.
Bottom : amplitude image, die-attach interface.

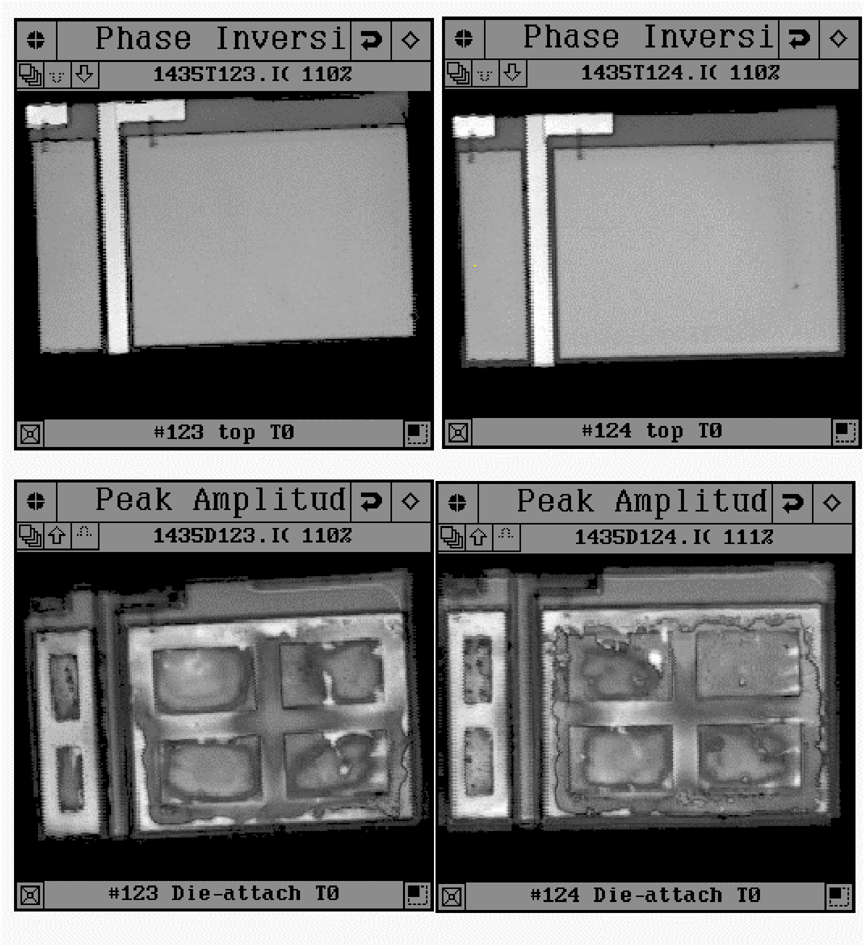


Figure 7. Acoustic microscopy, parts 123 and 124 ; Initial.
Top : delamination image ; epoxy / die, epoxy / ceramic.
Bottom : amplitude image, die-attach interface.

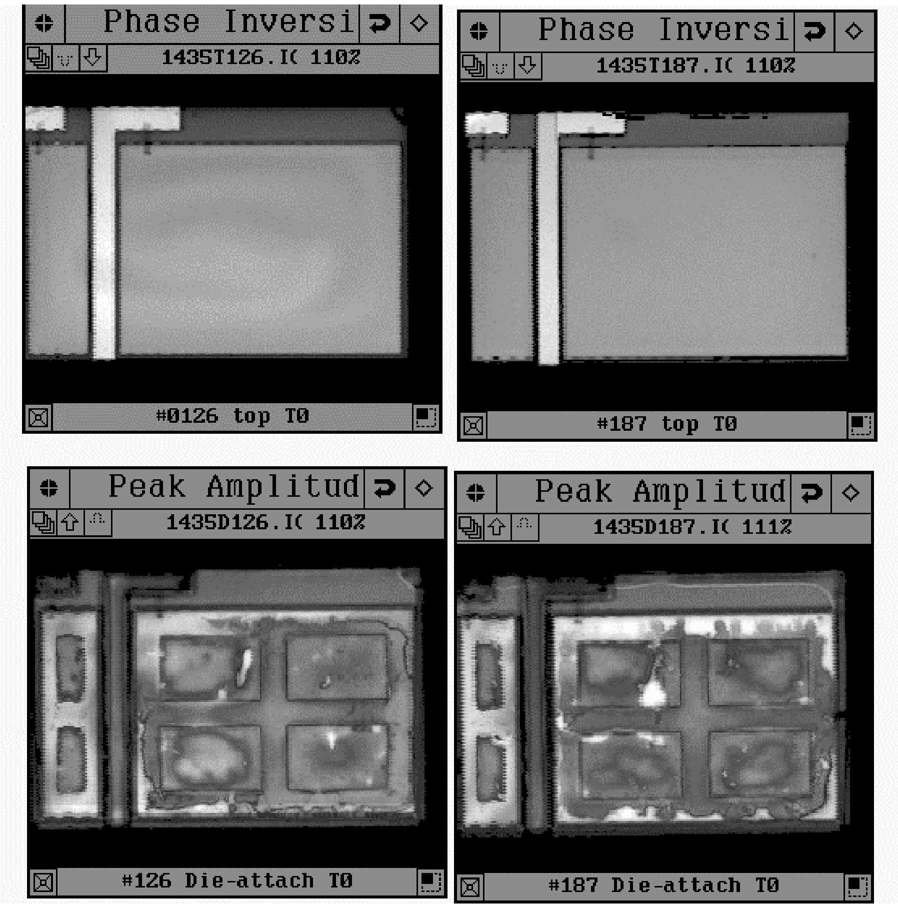


Figure 8. Acoustic microscopy, parts 126 and 187 ; Initial.
Top : delamination image ; epoxy / die, epoxy / ceramic.
Bottom : amplitude image, die-attach interface.

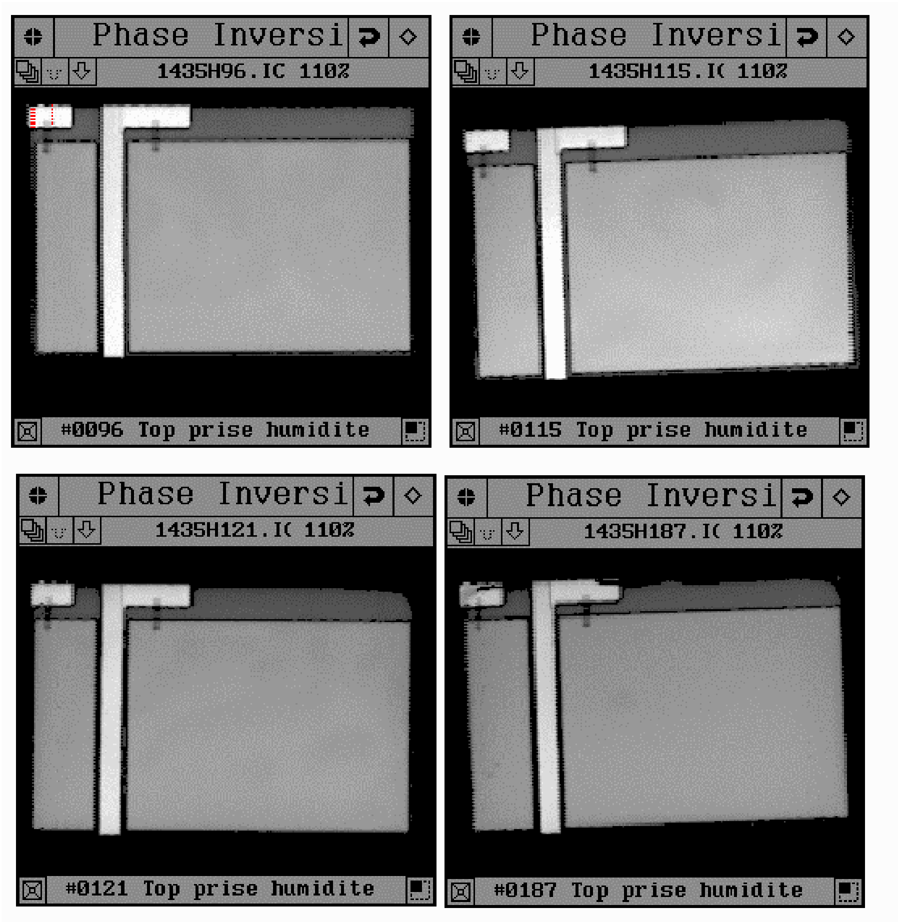


Figure 9. Acoustic microscopy, parts 96, 115, 121 and 187.
Temperature and humidity.
Delamination image ; epoxy / die, epoxy / ceramic.

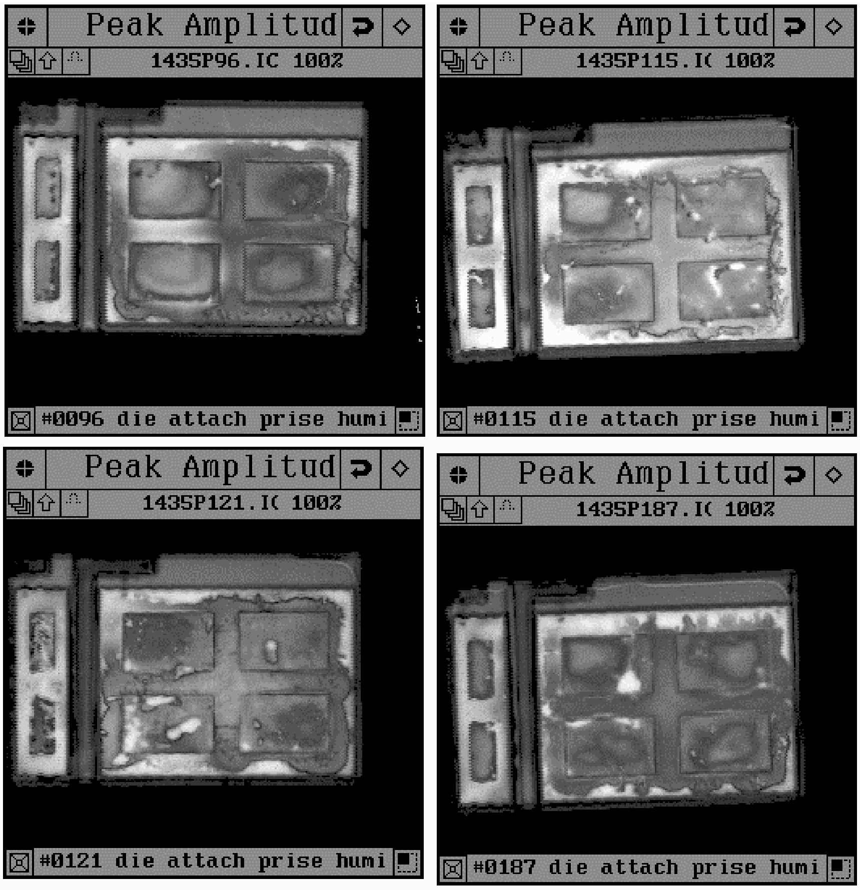


Figure 10. Acoustic microscopy, parts 96, 115, 121 and 187.
Temperature and humidity.
Amplitude image ; die-attach interface.

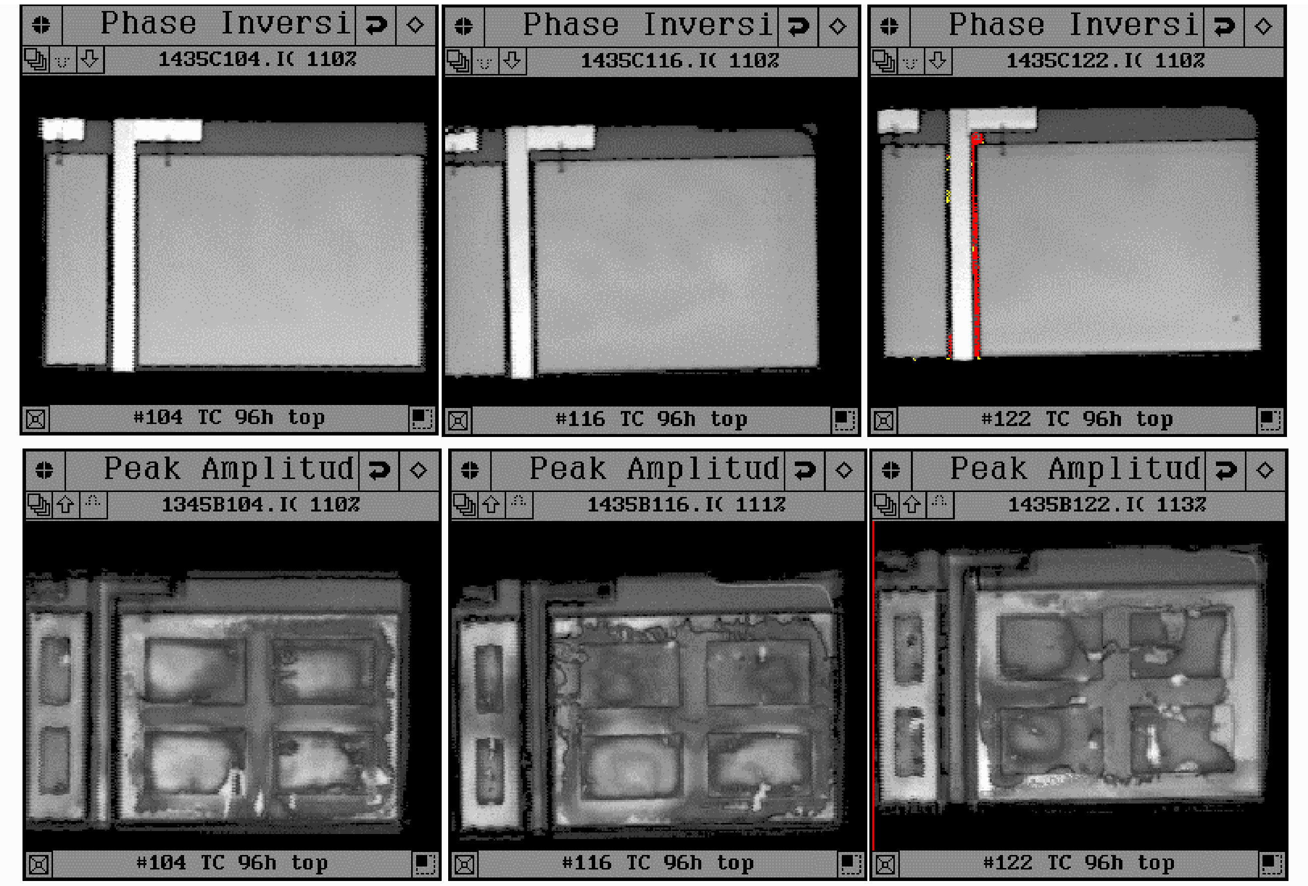


Figure 11. Acoustic microscopy, parts 104, 116 and 122.
Thermal cycling : 0°C / 50°C.
Top : delamination image ; epoxy / die, epoxy / ceramic.
Bottom : amplitude image, die-attach interface.

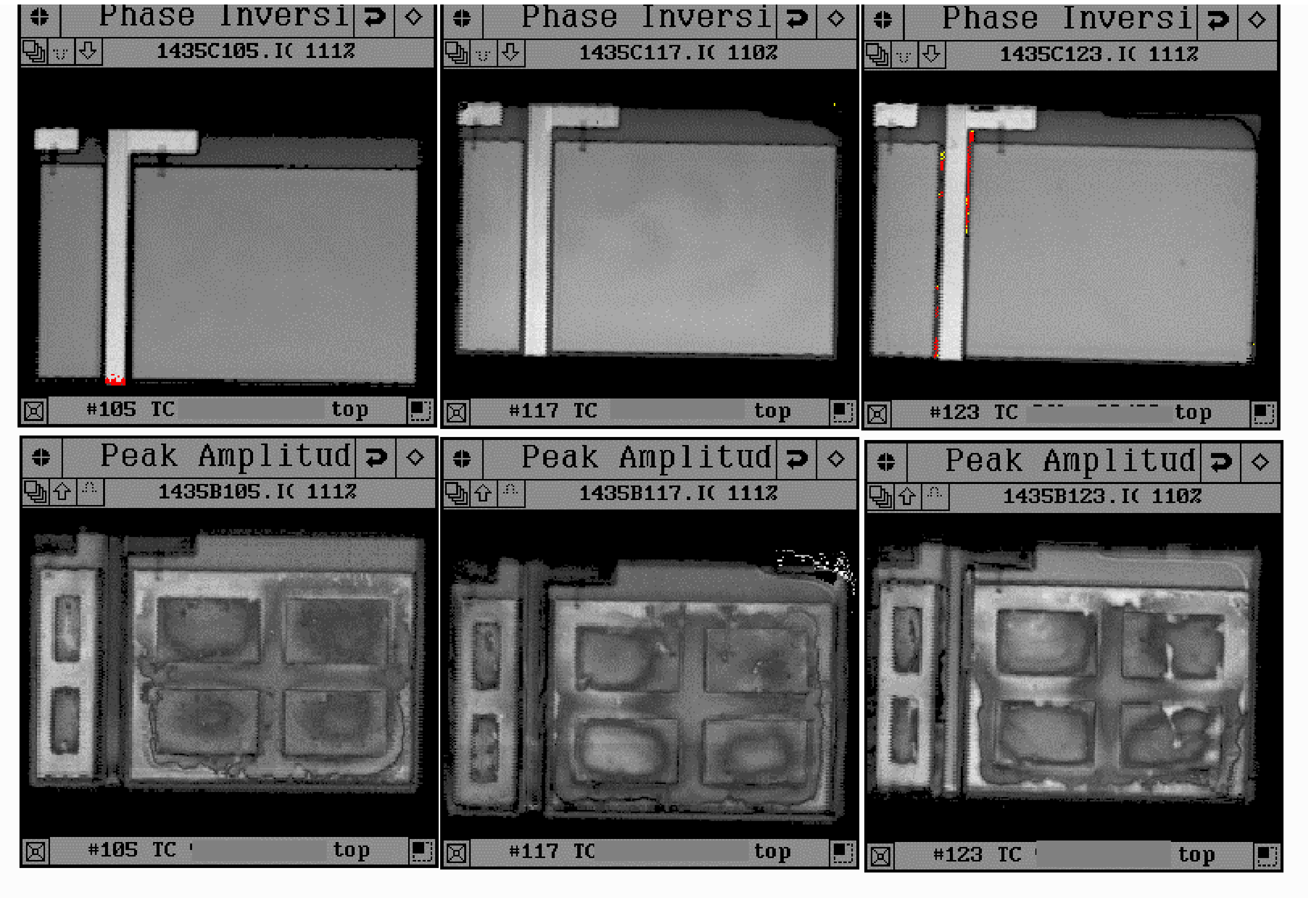


Figure 12. Acoustic microscopy, parts 105, 117 and 123.
Thermal cycling : -10°C / 60°C.
Top : delamination image ; epoxy / die, epoxy / ceramic.
Bottom : amplitude image, die-attach interface.

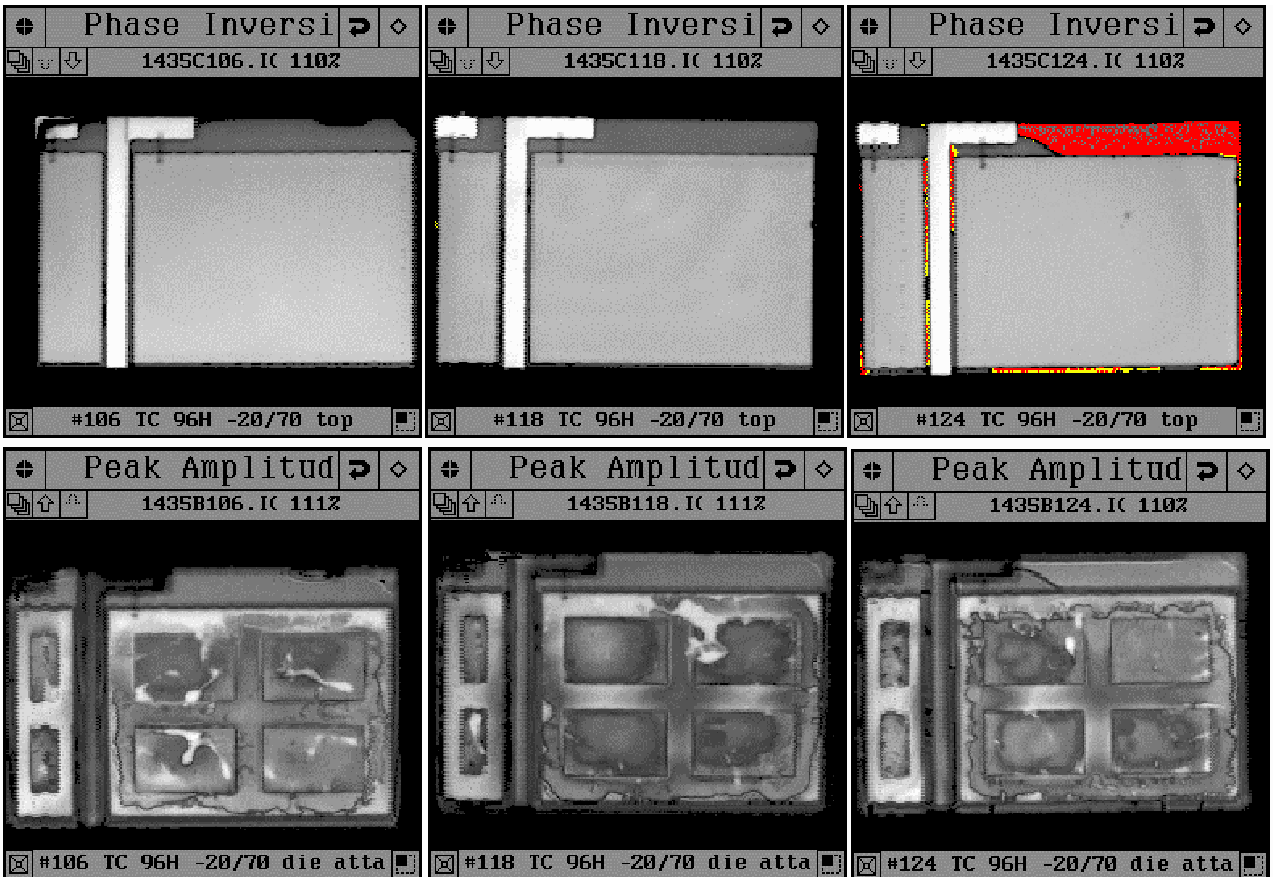


Figure 13. Acoustic microscopy, parts 106, 118 and 124.
Thermal cycling : -20°C / 70°C.
Top : delamination image ; epoxy / die, epoxy / ceramic.
Bottom : amplitude image, die-attach interface.

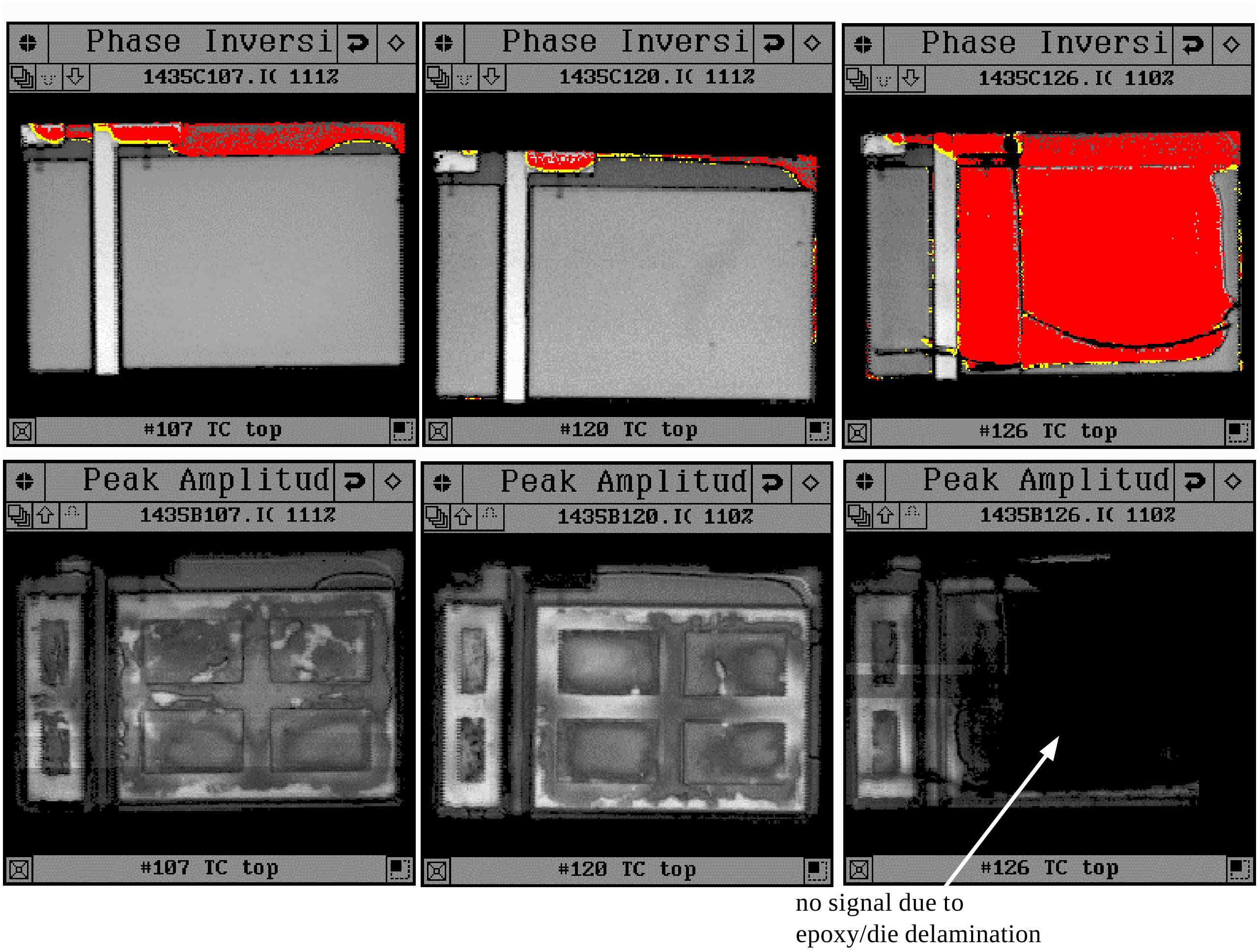


Figure 14. Acoustic microscopy, parts 107, 120 and 126.
Thermal cycling : -30°C / 80°C.
Top : delamination image ; epoxy / die, epoxy / ceramic.
Bottom : amplitude image, die-attach interface.

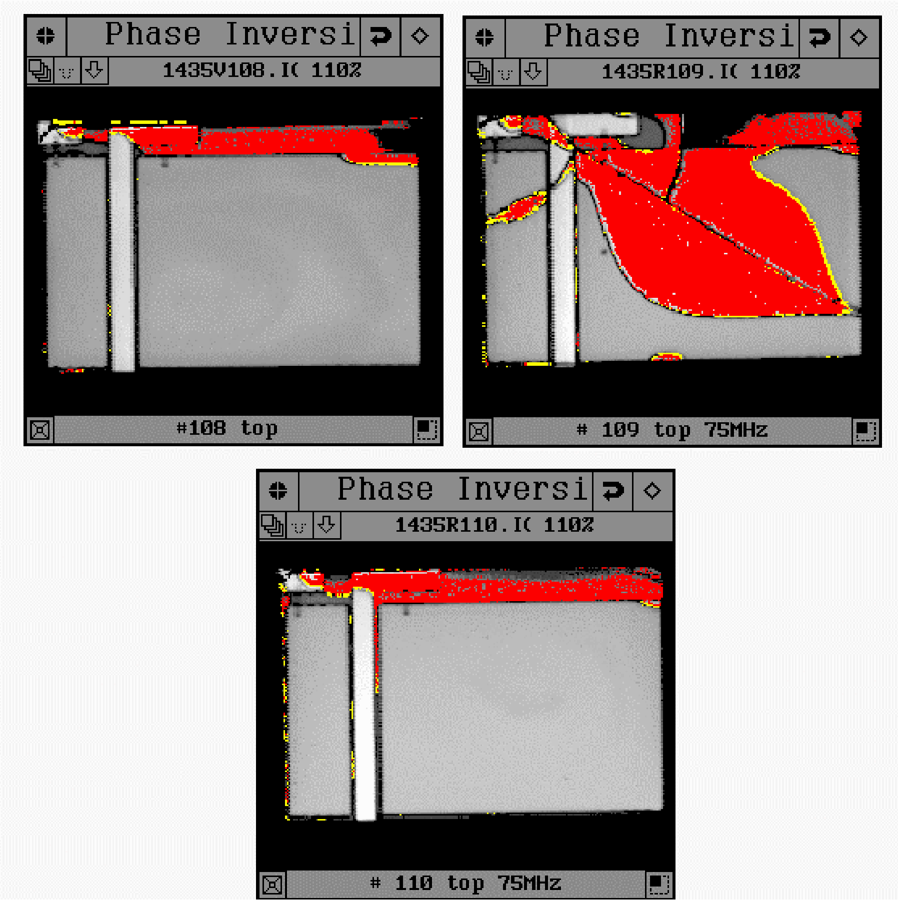


Figure 15. Acoustic microscopy, parts 108 to 110.
Thermal cycling : -40°C / 90°C.
Top : delamination image ; epoxy / die, epoxy / ceramic.

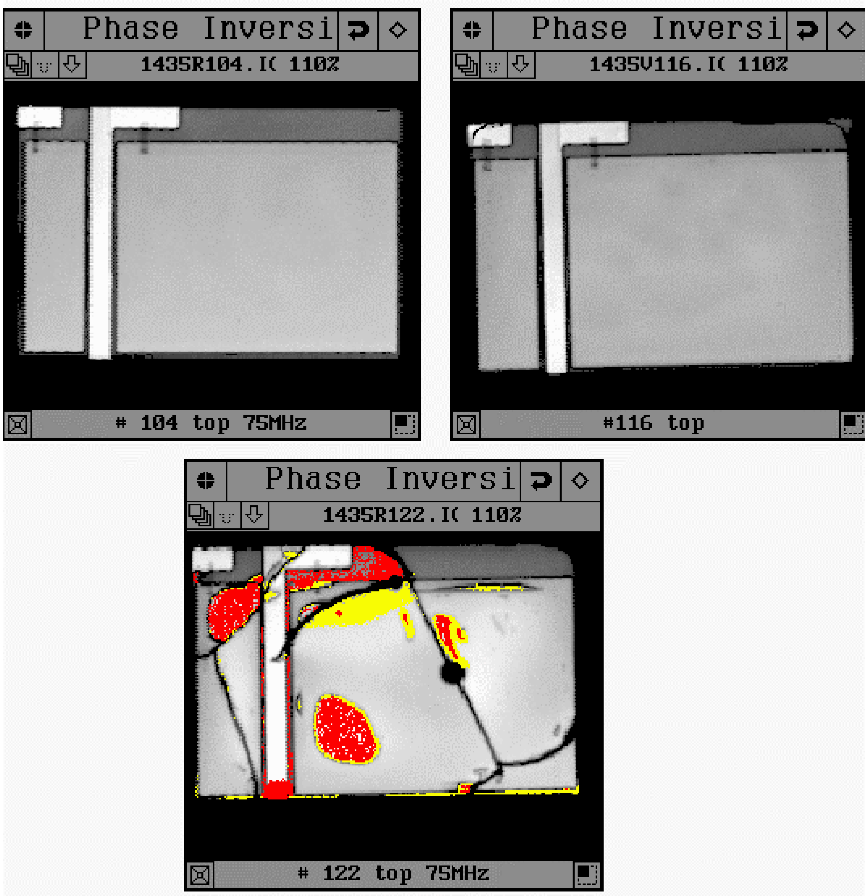


Figure 16. Acoustic microscopy, parts 104, 116 and 122.
Stress : -40°C, 168 hours.
Top : delamination image ; epoxy / die, epoxy / ceramic.

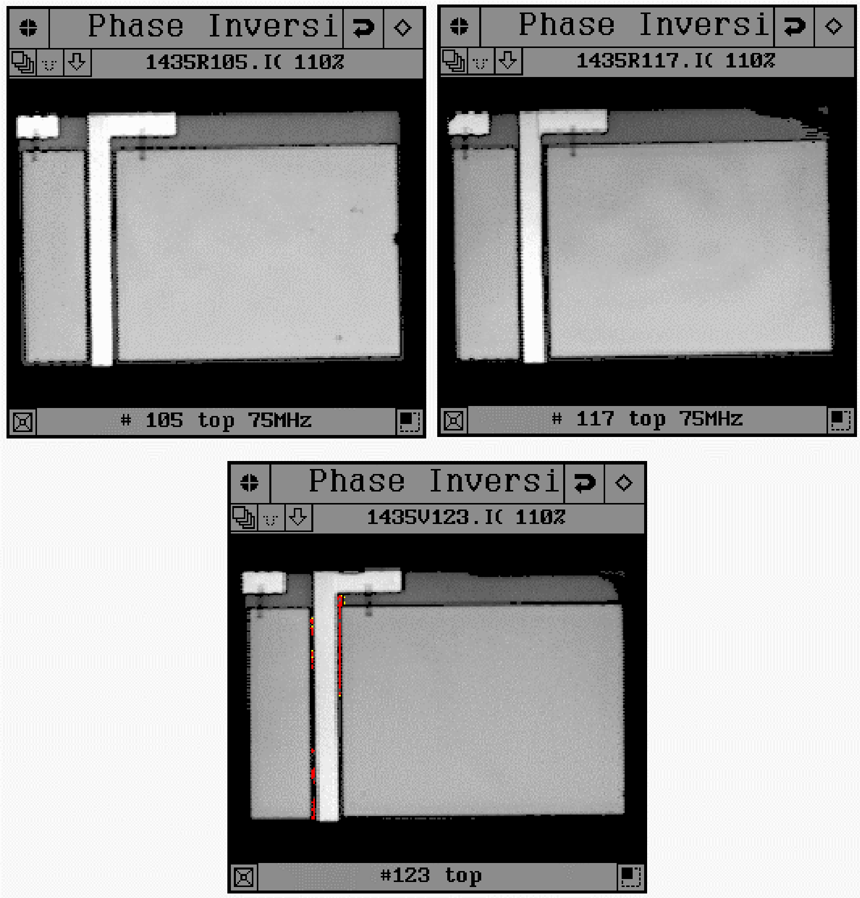


Figure 17. Acoustic microscopy, parts 105, 117 and 123.
Stress : 90°C, 168 hours.
Top : delamination image ; epoxy / die, epoxy / ceramic.

SERMA TECHNOLOGIES

E.B.I.C. INSPECTION ON DPD S85761G
FROM HAMAMATSU
(GLAST PROJECT)
REPORT E01P1435/03 - JUNE, 2002

This analysis was performed for :

CEA
Orme des Merisiers - BAT 709
91191 GIF-SUR-YVETTE

Performed by : M. LOPEZ

Approved by : D. TRIAS

Siège Social
30, avenue Gustave Eiffel
33608 PESSAC Cedex (France)
Tél : (33) 05.57.26.08.88 - Fax : (33) 05.57.26.08.98 – http : //www.serma.com

INTRODUCTION

During the evaluation of S85761G photodiodes, manufactured by *HAMAMATSU* (GLAST project), an inspection by Electrons Beam Induced Current (EBIC) was envisaged in order to inspect the dice surface.

Four diodes, referenced 0089, 0096, 0128 and 0187, were submitted for these investigations.

Parts 0089, 0096 and 0187 revealed a defective dark current (Pin B).

Part 0089 was used in order to develop a technique for protective gel removal.

Part 0128 was used for comparison.

CONCLUSION

* After different tests (Part 0089), a method was developed to remove the protective gel and keep the die functional. However no EBIC inspection was performed on this part.

* The EBIC inspection of the die was performed on Parts 0096 and 0187 Pin B and did not reveal any damage.

  This technique appeared satisfactory in order to detect defect in the bulk.

Note : an EBIC inspection was performed on Part 128 (Pin B, good part) and no difference was observed between parts with low dark current and high dark current.

PROCEDURE ANALYSIS

	0089 PIN B	0096 PIN B	0187 PIN B	0128 PIN B
	High dark current	High dark current	High dark current	Correct dark current
External inspection	X	X	X	X
Chemical decapsulation	X	X	X	X
Optical inspection	X	X	X	X
SEM inspection				
- ES		X	X	X
- EBIC		X	X	X

Procedure : PLAB009 "Traitement d'une analyse", SERMA Technologies internal procedure (12/05/2001)

ANALYSIS RESULTS

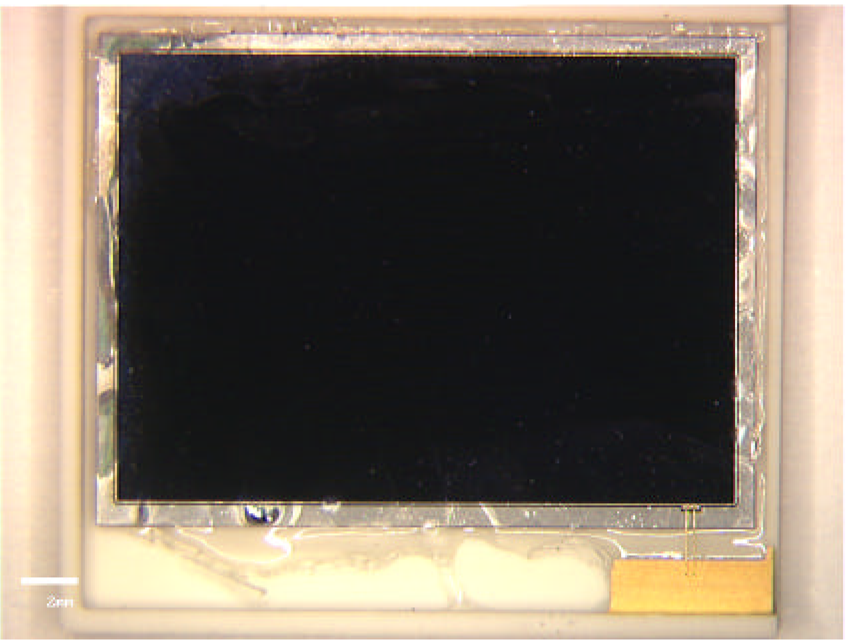
- The external inspection of each module was performed under binocular and did not reveal any concern.
  The two dice were mechanically insulated in order to perform functional opening.
  The gel at the dice surfaces did not allow an EBIC inspection. We had to determine a method to remove this gel with a correct functionality of the die (intact connections).

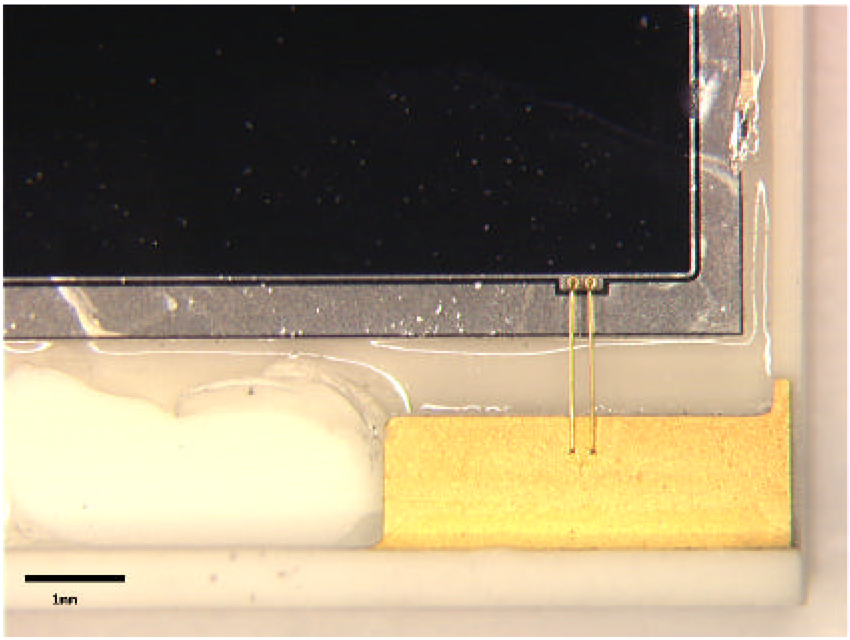
- On Part 0089 Pin B, a method with two solvents has permitted to remove the protective gel.

- The optical inspection of the dice surfaces did not reveal any defect.

- A SEM inspection by secondary electrons (ES) and by electrons beam induced current (EBIC) did not reveal any defect (Part 0096 and 0187, Pin B).
  No defect as black areas characteristic of defect in the bulk was identified in this part.
  This EBIC technique appeared satisfactory in order to inspect defect in the die.

- The Part 0128 Pin B with correct dark current was used for comparison with the other parts : no difference was observed.





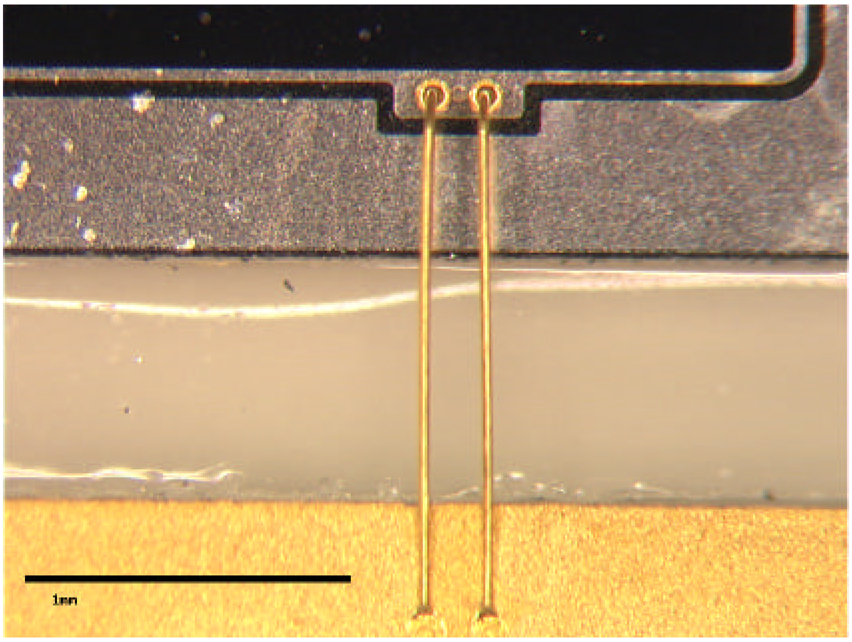
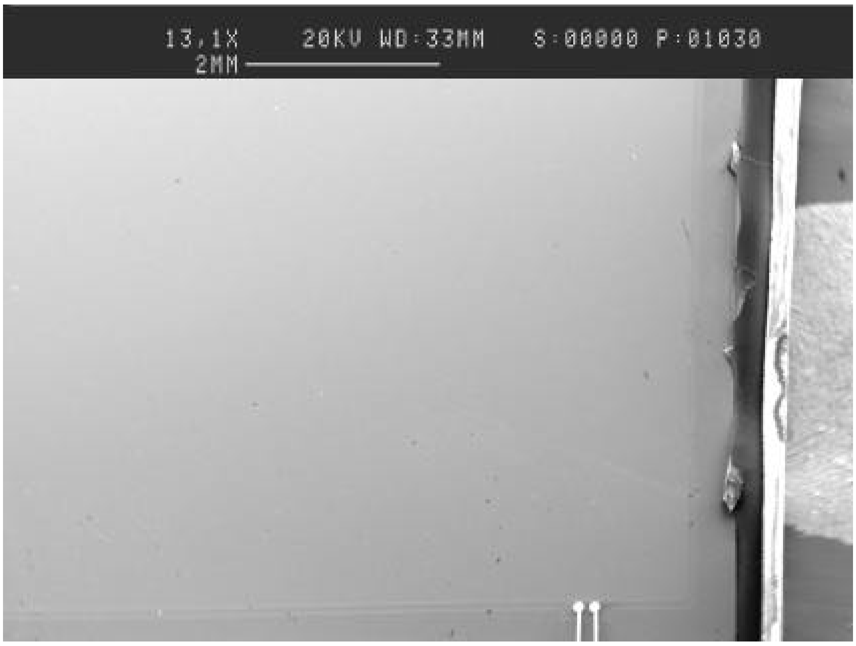


Figure 1. General and detailed external optical views of the die, Pin B, # 0096.
Top : mag 5X ; center : mag 15X ; bottom : mag 44X.



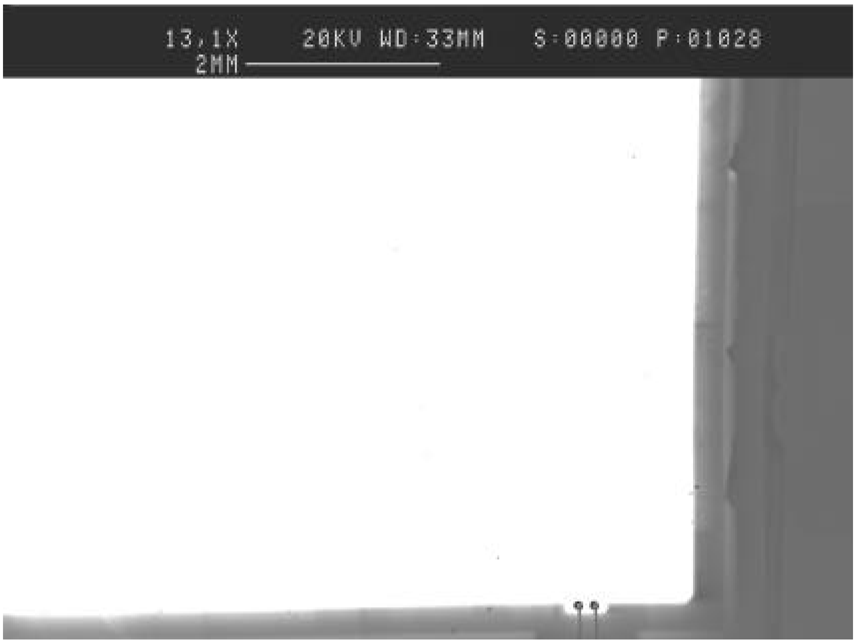


Figure 2. SEM detailed views of the die surface, Pin B, # 0096, mag 13X.
Top : secondary electrons view ; bottom : EBIC view.

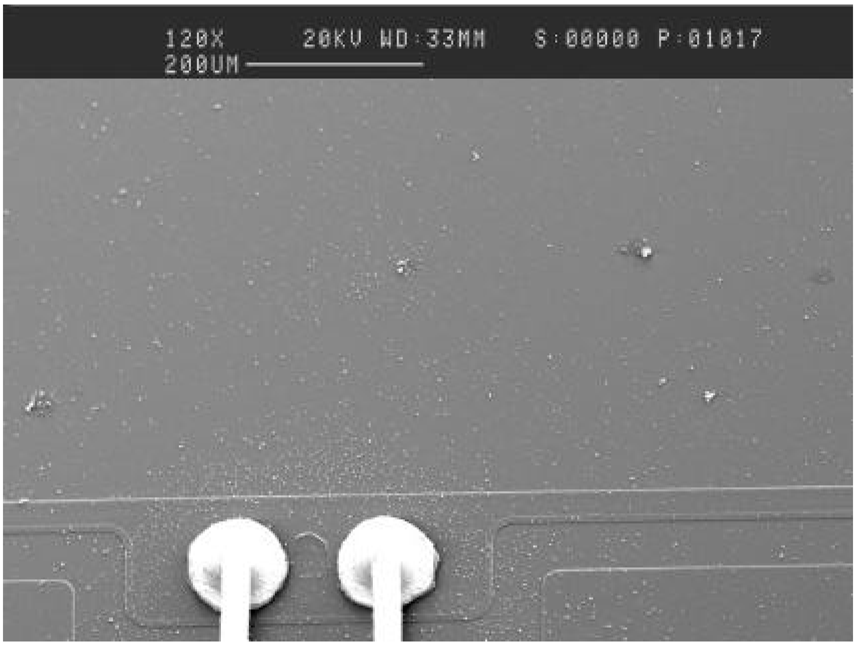
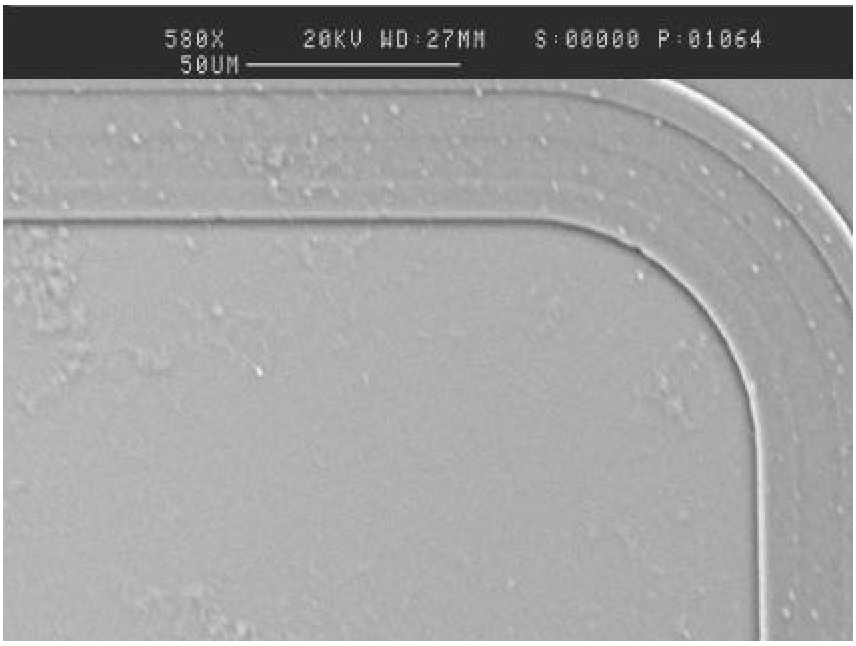


Figure 3. SEM detailed views of the die surface, Pin B, # 0096, mag 120X.
Top : secondary electrons view ; bottom : EBIC view.



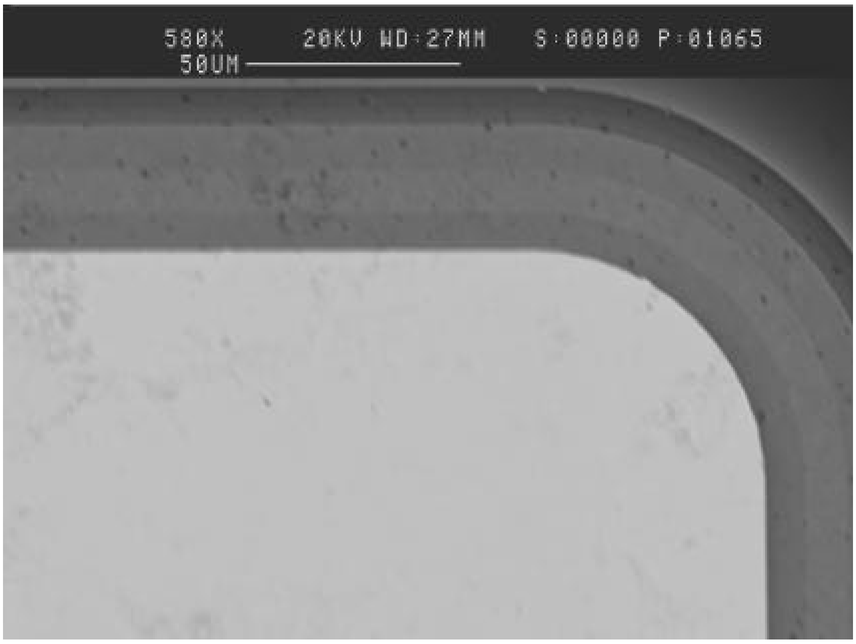
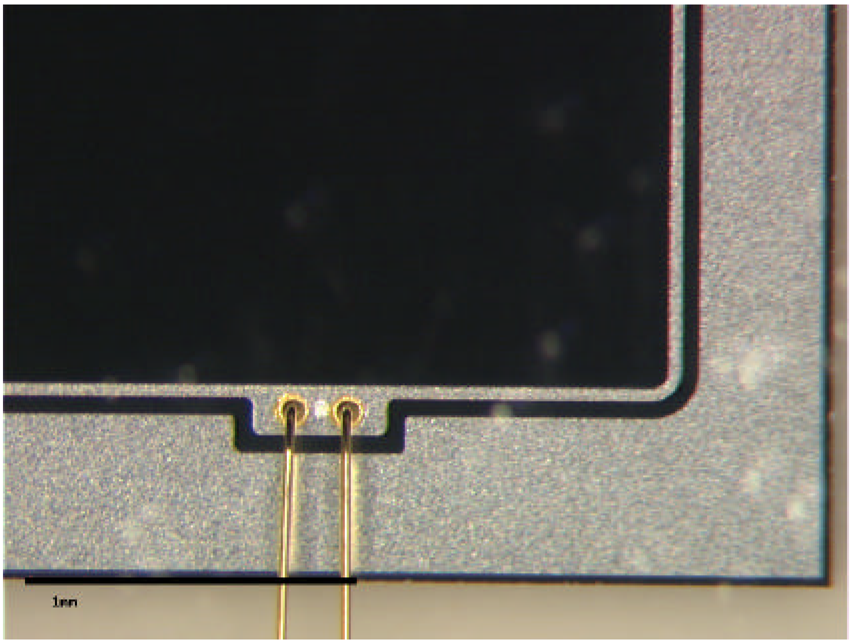
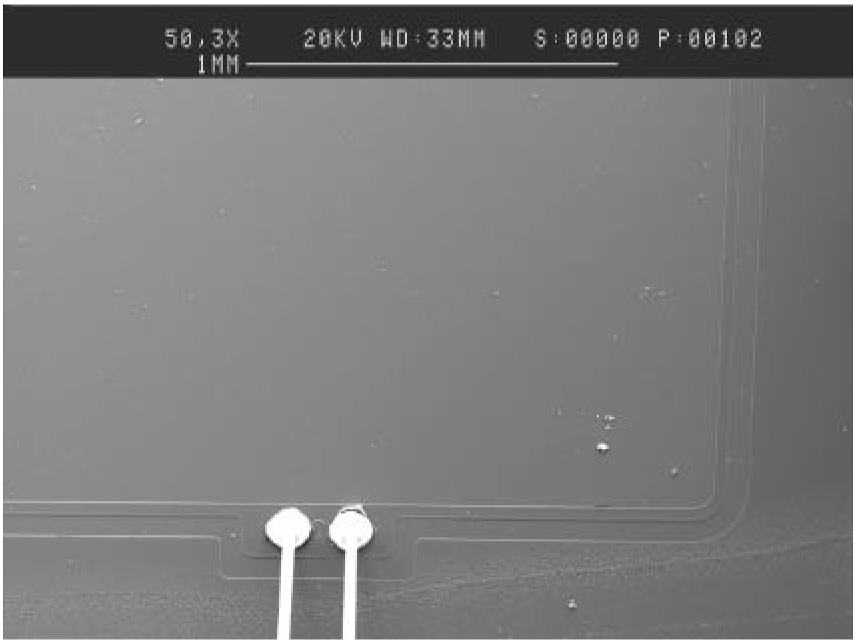


Figure 4. SEM detailed views of the die surface, Pin B, # 0187, mag 580X.
Top : secondary electrons view ; bottom : EBIC view.





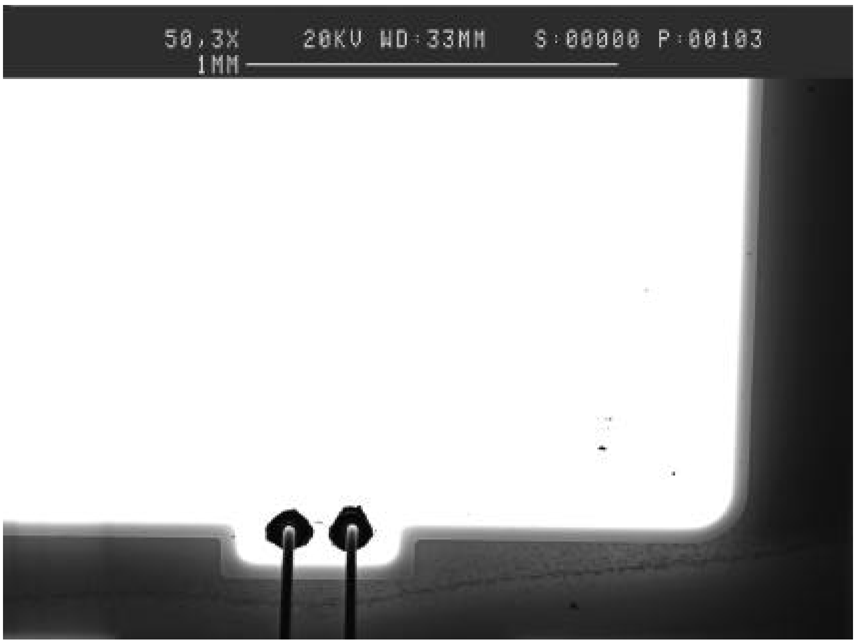


Figure 5. Optical and SEM detailed views of the die surface, Pin B, # 0128.
Top : optical view, mag 45X ; center : Secondary Electrons SEM view, mag 5X ;
Bottom : EBIC SEM view, mag 50X.

ANNEX

SERMA TECHNOLOGIES

BENDING TEST ON A
DPD S8576 FROM HAMAMATSU
ANNEX TO REPORT E01P1435/01
JUNE, 2002

This analysis was performed for :

CEA
Orme des Merisiers - Bât. 709
91191 GIF-SUR-YVETTE

Performed by : P. BARRET

Approved by : JM. ETCHARREN

INTRODUCTION

One Dual PIN photo Diode (DPD) from *HAMAMATSU*, was submitted to SERMA Technologies for terminations bending test.

The part external marking was the following : S8576 2B (without serial number, this part is a rejected part from HAMAMATSU).

RESULTS

* Test condition :

  According to the IEC pub. 6008-2-21, bending test Ub, Method 1 :

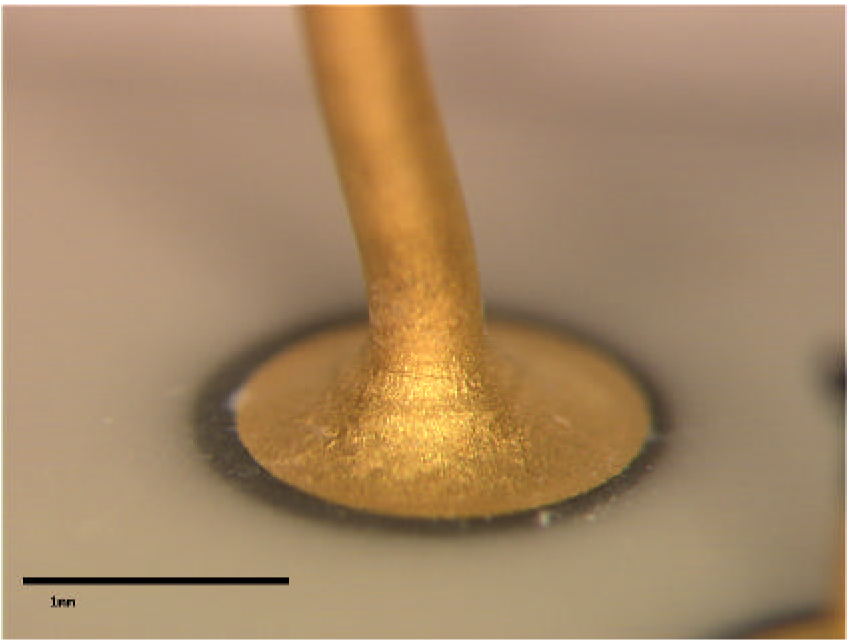
  - applied force : 2.5 N
  - two bends in opposite direction at 90° each from vertical axis
  - all terminations tested

* Results :

  No significant degradation was found after the test. The part is acceptable (Figures 1 to 3).
  SEM inspection of the lead attach to case areas shows small cracks located in coating layers, they appeared to be normal in view of the stress applied.

Notes : - before the test (initial visual), one lead evidenced a gold coating blister ; it was increased after testing (Figure 1 bottom).

- one lead was bent a number of time sufficient to be broken : five bends at 90° were performed from vertical axis. For this stress, the lead was held with a pliers close to the case, that was a very strong stress
  This test confirms the good mechanical strength of the lead.



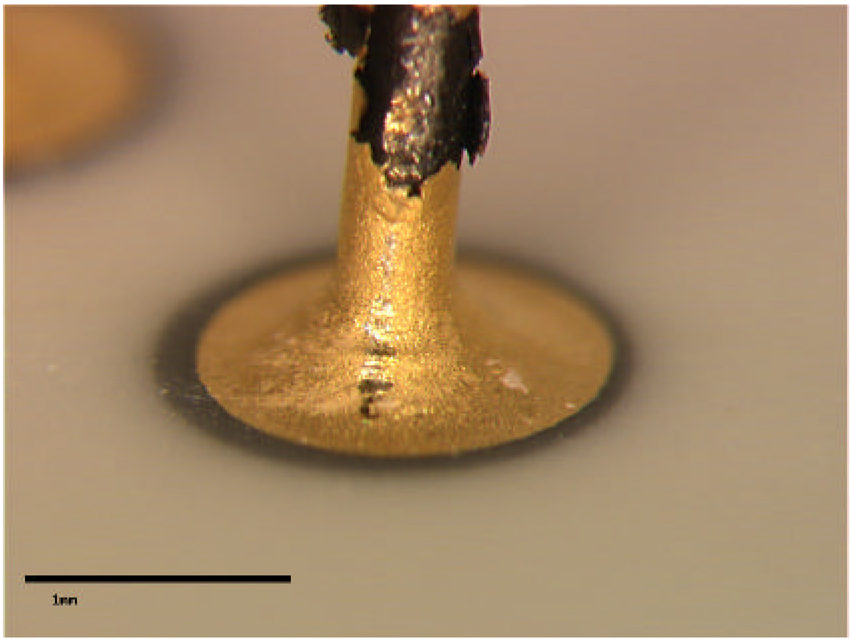
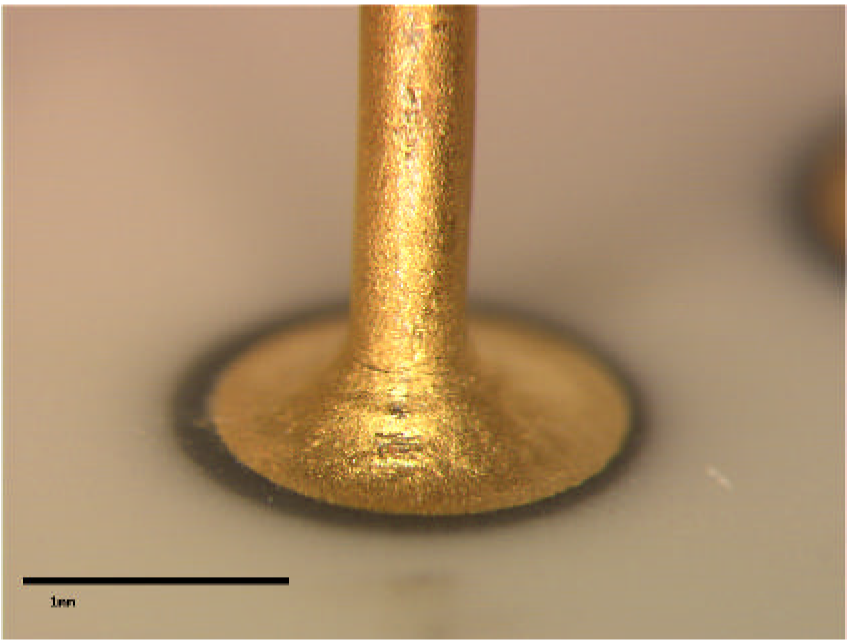


Figure 1. Optical views of lead bases after bending test, ≈ 36X.



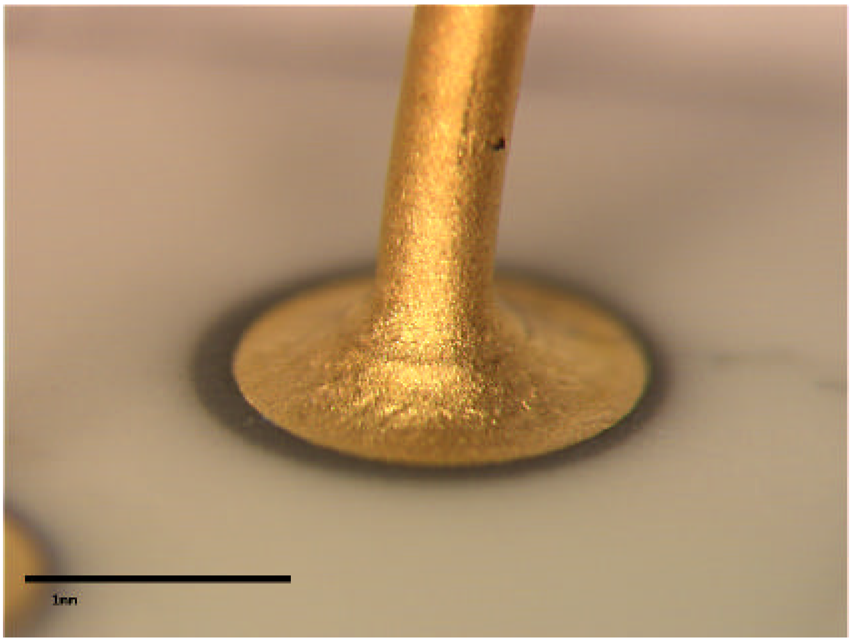
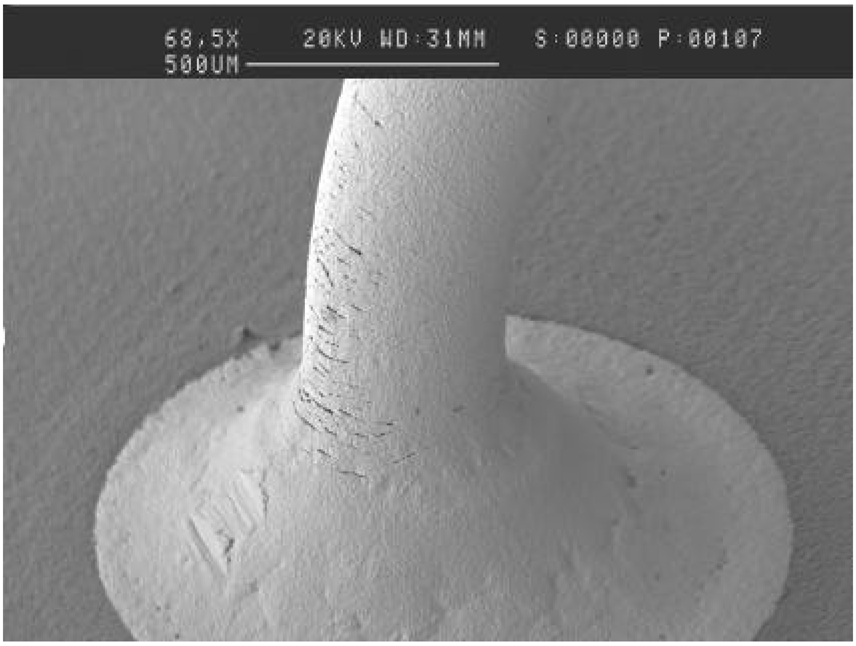


Figure 2. Optical views of lead bases after bending test, ≈ 36X.



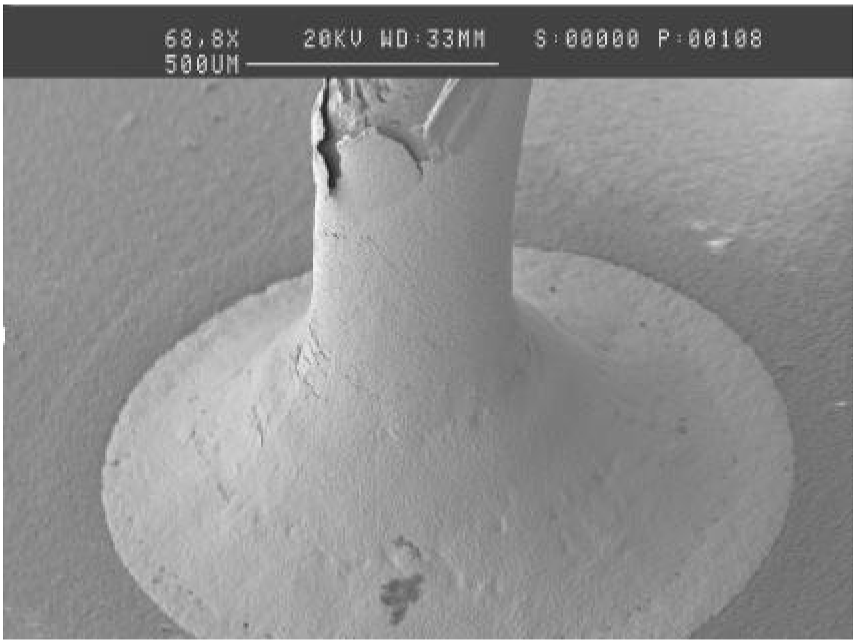
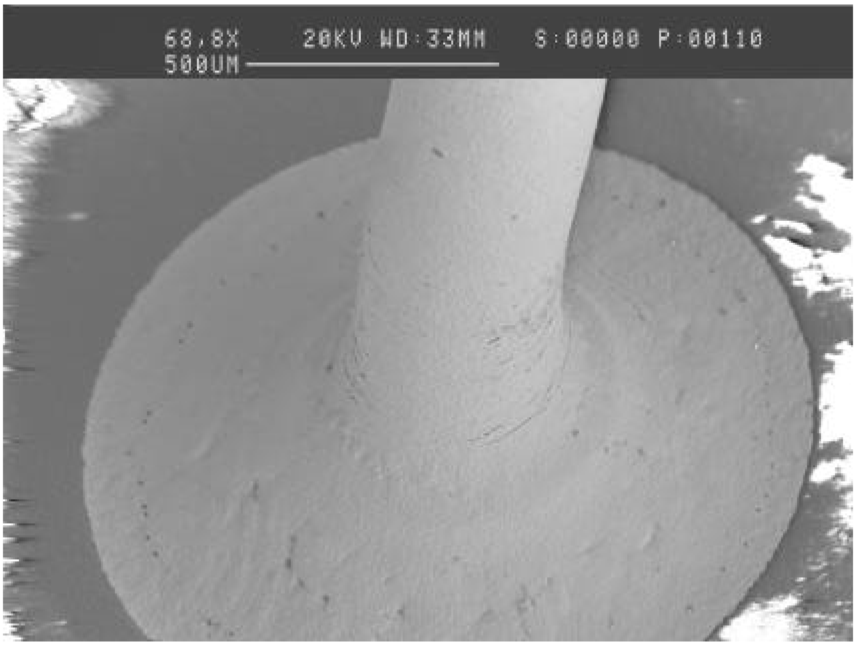


Figure 3. SEM views of lead bases after bending test, ≈ 70X.



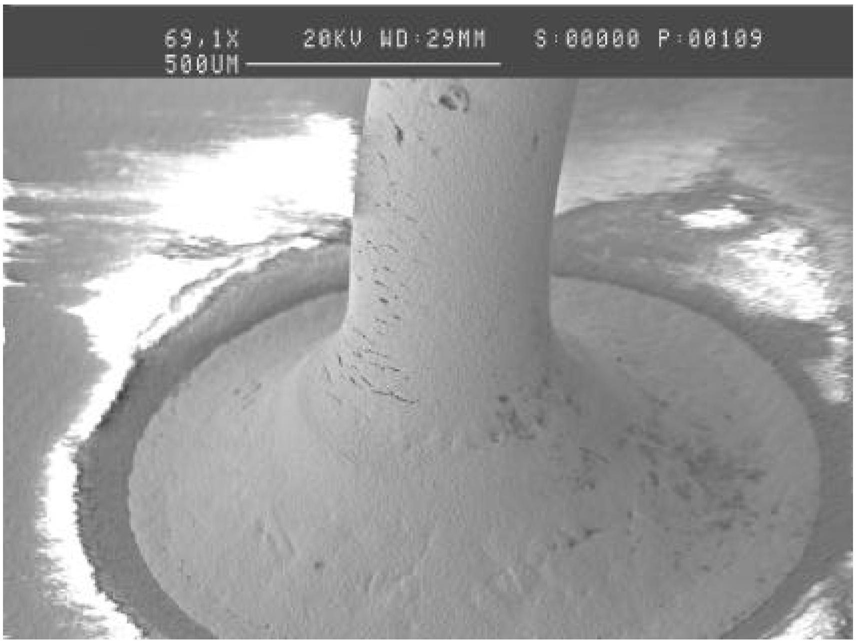


Figure 4. SEM views of lead bases after bending test, ≈ 70X.